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AUTOMOBILE EXHAUST EMISSION SURVEILLANCE

Calspan Corporation

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AUTOMOBILE EXHAUST EMISSION SURVEILLANCE

A SUMMARY

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Prepared by

CALSPAN Corporation
Buffalo, New York

Contract No. 68-01-0435

EPA Project Officer: Charles J. Domke

Prepared for

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Certification and Surveillance Division
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1. SUMMARY, CONCLUSIONS AND BACKGROUND

The purpose of this report is to summarize information on emissions from light-duty vehicles. State and local agencies, Federal air pollution officials, automobile manufacturers and concerned citizens can use this report to estimate the impact that light-duty vehicle emissions have on air quality and to determine conformity of vehicles to the standards under which they were certified. Contained in the report are the findings and results of three exhaust emission surveillance programs conducted by the EPA: (1) the Great Plains (Two-City) Surveillance Program--1968-1969 Model Year Survey; (2) the National Surveillance Program--1970 (Six City) and 1971 (Four City) Model Year Surveys; and (3) a Study of Emissions from Light-Duty Vehicles in Six Cities--1957-1971 Model Year Survey. The first two programs employed the Federal Seven-Mode Test Procedure, whereas the third program utilized the 1972 and 1975 Constant Volume Sampling (CVS) Federal Test Procedure.

The Congress, through the enactment of the Clean Air Act of 1963 and amendments thereto, provided for a national air pollution program to monitor and control emissions from new motor vehicles. Administrative responsibility for the air pollution control program is vested with the U.S. Environmental Protection Agency (EPA). The first nationwide standards, together with the testing and certification procedures, were issued in 1966 and were applicable to 1968 model year passenger vehicles and light-duty trucks sold within the United States. Levels for maximum allowable emissions were imposed initially on hydrocarbon (HC) and carbon monoxide (CO) effluents only. Hydrocarbons were restricted to 275 parts per million concentration and carbon monoxide was restricted to 1.5 percent.* These effluents were measured using the 7-mode cold start test procedure. More stringent standards were introduced for 1970 and 1971 model vehicles. The Federal standards based on the 7-mode procedure, expressed in mass equivalents, were 2.2 grams/mile for HC and 23 grams/mile for CO. In 1972, a change was made to a new test procedure. This procedure contained a new sampling method, the Constant Volume Sampling Procedure (CVS), and a new driving sequence. At that time the standards were again strengthened. The first Federal standards applicable to oxides of nitrogen were promulgated for 1973 model year light-duty vehicles.

The surveillance studies in this report were done using the test procedure in effect at the time of the study. Although correlation factors have been developed to relate the 7-mode and CVS Federal test procedures, they are based on average results of a sales-weighted sample of many different vehicles. For this analysis, it is more appropriate to treat the results of tests made by the two procedures without endeavoring to translate these results from one procedure to the other.

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* These were the standards for vehicles with engines greater than 140 cubic inches displacement. Vehicles with engines which did not exceed 100 cubic inches displacement were restricted to 410 ppm HC and 2.3 percent CO.

1.1 SUMMARY

Hydrocarbon and carbon monoxide emissions for the vehicles tested were assessed by comparing their mean emission levels with applicable Federal standards. Such comparison is consistent with the goals of pre-1972 regulations, which were aimed at insuring that average vehicle emission levels met standards. NO_x emissions, which were not subject to control during the model years covered by the programs, showed an increase of approximately 35 percent from measurements on pre-1968 vehicles to measurements on post-1968 vehicles. In general, hydrocarbon and carbon monoxide emissions showed a significant downward trend with newer model vehicles. The most recent study, a survey of 1957 to 1971 model year vehicles based on the 1972 CVS Federal Test Procedure, shows this downward trend in emissions. The following table displays the percent of EPA's goal which has been achieved:

Percent of Emission Reduction Achieved

Model Year	Date Tested	Percent of Goal Achieved* HC	CO
1971	1971	99%	85%
1970	1971	84%	69%
1969	1971	58%	38%
1968	1971	54%	30%

This table is based on a comparison of actual emissions with the 1972 Federal standards. The actual emission standards for 1968-1971 vehicles for HC and CO, in terms of converted 7-mode standards, were less stringent. Thus the use of the 1972 Federal emission standards as a point of reference to evaluate the percentage of the emission reduction goal that has been achieved for the model years 1968 through 1971 results in a conservative estimate of improvement. In that context, it should be noted that the imposition of stricter standards tends to cause a step-function improvement in vehicle exhaust emissions, as can be seen by examining the difference between 1969 and 1970 model year vehicles.

In an effort to assess the extent to which local climate, terrain, driving practices and other geographically differentiated factors affect emissions, vehicles were sampled in several cities, selected to span the range of such factors. Only small differences were observed in the emissions measured in the cities included in the survey, the only notable exception being Denver. Significantly higher carbon monoxide and hydrocarbon emissions and lower NO_x emissions were observed in Denver than in the other cities, presumably because of the effect of altitude on air-fuel ratios.

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* See Appendix I for additional information on the development of this table.

The effect of mileage accumulation on vehicle functioning, as reflected by measurable changes in emission levels, was explored by making two or more emission measurements on the same vehicle at different points in its mileage-accumulation history. The effect of mileage accumulation on emission levels was shown to be highly variable from one vehicle to another. With the exception of Denver, when emissions increased with mileage, vehicles with initially low mileages (less than 60 miles) exhibited a greater change in emission levels per 1000-mile increment of mileage than did vehicles having initial mileages in the 20,000- to 30,000-mile range.

The test programs were conducted on as-received vehicles and the test results may reflect to some extent the influence of such variables as state of maintenance and repair. The statistical distribution of automobile exhaust emissions for "as received" vehicles is skewed toward the high end of the distribution curve. If the distribution were symmetrical and fifty percent of the vehicles met the standard, the mean of all the vehicles would also meet the standard. This relationship does not apply, however, with a skewed distribution. If an indication of total mean emissions is desired with a skewed distribution, the mean emission level of a group of vehicles must be looked at independently of the percent of these vehicles which conform to the standard.

1.2 CONCLUSIONS

Results of the three automobile exhaust emissions surveillance programs summarized in this report reveal the following:

1. Exhaust emission levels depend on a number of factors peculiar to a specific vehicle, including its make and its accumulated mileage.

2. Though statistically significant differences were observed in the mean emission levels in different cities, Denver was the only city showing consistent differences of sufficient magnitude to be of engineering significance. Carbon monoxide and hydrocarbon emissions tended to be higher in Denver than in other cities, whereas oxides of nitrogen tended to be lower. The observed differences are believed to be attributable to the effect of altitude on air-fuel ratios. There was some indication that CO and HC emissions were somewhat lower and NO_x emissions somewhat higher in Los Angeles than in the other cities, but the differences were not as marked as for Denver and not judged to be of practical significance.

3. Individual vehicles of a particular category show wide dispersion in exhaust emissions. Consequently, two categories of vehicles, such as those tested in two

different cities, may show considerable overlap of their statistical distributions even though the mean emissions for the two categories are appreciably different. Generalizations with regard to make, city or other categories of interest, therefore, are often not applicable to comparison of individual vehicles or small subsets of vehicles drawn from the two categories.

4. In the surveillance tests of 1968 and 1969 year vehicles in Kansas City and Houston, the following observations were made, based upon the 7x7 Federal Test Procedure.

   a. 46% of the 1968 model year vehicles tested individually complied with applicable standards for HC, that is, 46% of the vehicles exhibited emission levels below the level allowable by the standard. Similarly, 35% were below standards for CO, and 23% were below standards for both HC and CO. Mean emission levels for HC, CO and NO_x were 352 ppm, 2.14%, and 1275 ppm, respectively.

   b. The mean emission levels for both the 1968 and 1969 model year vehicles exceeded the applicable standards of 275 ppm HC and 1.50% CO.

   c. 53% of the 1969 model year vehicles were below applicable standards for HC, 42% were below standards for CO, and 30% were below standards for both HC and CO. Mean emission levels for HC, CO and NO_x were 303 ppm, 1.86% and 1453 ppm, respectively.

5. In the surveillance tests of 1970 model year vehicles in Kansas City, Houston, Los Angeles, Detroit, Denver and Washington, the following observations were made, based upon the 7x7 Federal Test Procedure.

   a. With Denver vehicles excluded, 32% of the vehicles tested were below applicable standards for HC, 35% were below standards for CO, and 19% were below standards for both HC and CO. In Denver, the corresponding percentages were 5%, 3%, and 0.3%.

   b. In general, the mean emission levels of the vehicles tested exceeded the applicable standards of 2.2 gms/mi, and 23.0 gms/mi for HC and CO, respectively.

   c. Mean emission levels for HC, CO and NO_x for all cities except Denver were 2.83 gms/mi, 35.3 gms/mi and 4.69 gms/mi, respectively. The corresponding values for Denver were 4.25 gms/mi, 65.1 gms/mi, and 3.83 gms/mi.

6. In the surveillance tests of 1971 model year vehicles in Houston, Los Angeles, Detroit and Denver, the following observations were made.

   a. Low-mileage (less than 60 odometer miles) and stabilized engines showed distinct differences in the percentage of vehicles tested which were below applicable standards for HC, CO and both HC and CO.

		Percent Below Standards for		
		HC	CO	Both
Total Excluding Denver:	Low Mileage	87	60	58
	Stabilized	59	49	38
Denver Only:	Low Mileage	36	2	1
	Stabilized	29	10	6

   b. Mean emission levels for HC, CO and NO_x for low mileage and stabilized engines were as follows:

		HC	CO	Both
Total Excluding Denver:	Low Mileage	1.47	23.7	3.16
	Stabilized	2.12	29.0	3.74
Denver Only:	Low Mileage	2.63	64.0	2.96
	Stabilized	3.16	45.2	3.19

   c. Applicable standards of 2.2 gms/mi HC and 23.0 gms/mi CO were, for the most part, exceeded by the higher mileage and correspondingly older stabilized engines, which would most nearly represent engines operating in vehicles in general use.

7. Mileage accumulation has a statistically significant effect on exhaust emissions, but the effect varies strongly from one vehicle to another and may be confounded with attendant factors such as state of maintenance. In most of the cases analyzed, nearly equal numbers of individual vehicles showed increasing and decreasing emission levels with mileage accumulation. On an aggregated or average basis, however, significant trends were established. For stabilized engines, these trends were of the order of 0.5% to 1.0% per thousand miles, with HC and CO increasing and NO_x decreasing. Engines having low initial mileages were shown to exhibit more pronounced changes with mileage, typically 5% per 1000 miles. When all cities except Denver were considered, all three pollutants for low-mileage engines increased with mileage. When Denver was considered separately, HC and NO_x increased but CO showed a marked decrease with mileage.

8. Tests of light-duty vehicles, model years 1957 to 1971, show a consistent downward trend in HC and CO emissions from 1957 to 1971. The trend is highlighted by the following average emission levels based upon the 1975 CVS-CH Test Procedure for pre-control and controlled vehicles, excluding Denver and for Denver alone.

	Emission Levels (gms/mi) 1975 CVS-CH Test Procedure		
	HC	CO	NO_{xc}
Total Excluding Denver			
Pre-Control	8.74	86.5	3.54
Controlled	4.54	54.9	4.79
Denver Only			
Pre-Control	10.16	126.9	1.89
Controlled	6.46	92.2	2.67

These results are indicative of the effect of emission controls on air quality.

9. Tests of evaporative emissions using the SHED technique from 126 light-duty vehicles, model years 1957 to 1971, in Los Angeles show approximately a 30% decrease in evaporative emissions with the advent of California evaporative controls in 1970. Federal evaporative emission controls were instituted with model year 1971. This trend is demonstrated by the following average Diurnal, Hot Soak and Combined evaporative losses for pre-control vehicles and vehicles employing evaporative controls.

Evaporative Losses Using Enclosure Technique - HC - gms/Test

	Diurnal Mean	Hot Soak Mean	Combined Mean
Pre-Control	25.97	14.67	40.64
Controlled	16.28	10.92	27.20

In addition, evaporative losses for 1971 vehicles in Denver were found to be approximately two to three times larger than losses in comparable Los Angeles vehicles. The diurnal, hot soak, and combined mean evaporative losses per test for Denver vehicles were 47.2 gms HC, 34.77 gms HC and 81.97 gms HC, respectively.

1.3 BACKGROUND

Under the Clean Air Act, manufacturers are required to submit applications containing data gathered during both phases of a two-part test program in order to qualify for certificates of conformity. For model years 1968

through 1971, the first phase of testing provides data on exhaust emissions which show the performance of the control equipment after the engine has been broken in, but before substantial mileage has been accumulated. These data are known as 4,000 mile emission data. The second phase of the test program provides data on the durability of the emission control system. These data are known as 50,000 mile durability data. For the vehicle model years treated in this report, compliance was demonstrated whenever the mean emission level from a specified sample of emission-data prototypes of each engine displacement, according to projected sales volume, is within the applicable standard.* This mean incorporates a deterioration factor determined from a sample of durability-data prototypes representative of at least 70% of the manufacturer's engine displacement/transmission options. Test and certification procedures, together with the appropriate standards, are published in the Federal Register. Inherent in the method of certification is the fact that mean values for HC or CO near the standard make it possible for 50% of certification or in-use vehicles to be above the standard for either pollutant. If both pollutants are considered together, it is likely that more than 50% of the vehicles will be above standards. Consequently, the percentage of individual vehicles with both HC and CO emission levels simultaneously within standards may give an unduly pessimistic picture of the degree of compliance with standards.

EPA has recognized that a realistic assessment of the effectiveness of Federal air pollution regulations requires the measurement of emissions from production vehicles in the hands of the motoring public. Accordingly, a series of exhaust emission surveillance programs has been administered by the EPA during the past several years to obtain such definitive information. Test fleets of consumer-owned vehicles within various major cities were selected by make, model, engine size, transmission, carburetor and compression ratio in such proportion as to be representative of the normal production vehicles sold (or projected to be sold) for that model year in the United States.

The principal objectives of such surveillance programs have been to establish degree of conformity of in-use production vehicles with certification levels and to assess the effects on emissions levels resulting from the test locale (i.e., the influence of climate, topography and urban development), vehicle mileage accumulation and vehicle make/model/engine differences. (The National Source Inventory Section (NSIS) and the Office of Land Use Planning (OLUP) have been closely involved with these efforts.)

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* For 1972 and subsequent model-year vehicles, every vehicle tested in the certification sample must exhibit emissions below the applicable standard level.

2. RESULTS AND DISCUSSION

This section of the report is a discussion of the findings and the results of three surveillance programs which in the aggregate represent tests of over 5500 light-duty vehicles. These three programs are: (1) the Great Plains (Two-City) Surveillance Program--1968-1969 Model Survey, (2) the National Surveillance Program--1970 (Six-City) and 1971 (Four-City) Model Year Surveys, and (3) "A Study of Emissions from Light-Duty Vehicles in Six Cities" (1957-1971 model vehicles). The emissions data collected in each of the first two programs cited above are susceptible to comparison and correlation as they all were measured using the seven-mode cold-start Federal Test Procedure and NDIR (non-dispersive infrared) instrumentation for effluent measurement. The last-cited program made use of both the 1972 (CVS-C) and 1975 (CVS-CH) Federal Test Procedures and utilized different instrumentation for measurement of HC (a flame ionization detector, FID) and NO_x (a chemiluminescent detector). A summary and overview of the procedures, sample size, test locations and objectives of these several programs are presented in Tables 1 and 33.

Although numerical results appearing herein have been drawn liberally from contractors' final reports for each of these programs, additional and different types of data analyses have been performed to provide additional perspectives and insights into the results and, in some cases, to broaden or refine the application of statistical methodology. In the formulation of conclusions, caution has been exercised to consider inherent sampling biases, confounding factors and other limitations that are associated with the data base. The results of data analysis have been interpreted pragmatically from the standpoint of the magnitudes of the emissions measurements as well as from the standpoint of the statistical significance levels associated with the results.

2.1 SEVEN-MODE TESTS OF 1968-1971 MODEL VEHICLES

This section of the report consolidates the data from two different surveillance programs which employed identical test procedures and analytical instrumentation in the collection of exhaust emission data. Composite exhaust emissions data taken from each vehicle tested were based on the seven-mode, cold-start test procedure as stipulated by the Federal Register appropriate to the model year involved. A brief descriptive summary characterizing these two programs is given in Table 1. It is seen that the project objectives have been directed to the evaluation of those factors that impinge most vitally on the ultimate success of realizing the goals of the national clean air program: the extent to which vehicles on the road meet emission standards, the atmospheric loading created by vehicle emissions, and the possible effects on emissions of vehicle mileage and geographic differences.

In all cases, an attempt was made to select the test fleets from the motoring public according to a strategy that yielded a sample as nearly representative as possible of the vehicles that were in use (or, in the case of new

models, projected to be in use). Vehicle categories were identified and selected by manufacturer and engine cubic-inch displacement (CID). In the case of the large manufacturers, such as General Motors, engines employed by different makes may be of different design despite sharing the same numerical value of displacement. In such cases, identification was by manufacturer, make and displacement. In the case of the 1968 and 1969 models, a total of 27 different CID engines was tested whereas the number increased to 44 for the 1971 models despite a decrease in size of the total test fleet from approximately 2,000 to 370 vehicles. Because of the effect of such limitations on the amount of data available in each vehicle category, emissions data for the most part in this report are summarized by manufacturer and make only. Where sufficient data exists, however, city and CID tabulations are presented.

The Federal Test Procedures applicable to the model years 1968 through 1971 remained substantially unchanged despite the fact that the certification standards and their dimensional units were revised. For 1968 and 1969, the standards for emissions were stated on a concentration basis, but in 1970 a change was made to the more realistic mass basis (grams/mile). Thus, for the most part, emissions data for 1968 and 1969 are presented in this report on a concentration basis, whereas data for 1970 and 1971 are presented on a mass basis. It is to be noted, however, that the change in basis is primarily one of data processing since the basic direct measurement was, and still is, in terms of concentration. A functional relationship was developed to calculate the vehicle exhaust volume per mile with vehicle inertia weight and transmission type as independent variables. By means of this relation, grams-per-mile values are calculable to afford a comparison of 1968, 1969, 1970 and 1971 model vehicles on a common basis. Although there were no standards for the oxides of nitrogen for these model years, the NO_x data were nonetheless measured and are included.

2.1.1 Results for 1968 and 1969 Model Vehicles

Exhaust emissions data for each of the three principal effluents determined from measurements on 1968-1969 model vehicles are shown by city in Tables 2 through 5. These data consolidate results from the three phases of this program during which time each vehicle, on the average, accumulated approximately 15,000 miles. Included in these tables are vehicles produced by American Motors (AMC), Chrysler (Chry), Ford (FoMoCo), General Motors (GM) and Volkswagen (VW) representing, in total, a statistical sampling of 90% of the sales for those model years.

The results are expressed as concentrations and should be assessed against the certification standards applicable to these models (275 ppm HC and 1.50% CO, except for VW, for which the standards are 410 ppm HC and 2.30% CO). Oxides of nitrogen are expressed as NO_{xc}, the subscript c denoting correction for humidity. For each of the vehicle categories listed, the tables give N, the number of tests, the mean mileage in thousands of miles, and emissions data in three different forms. First, results are expressed in terms of the percent of vehicles having emissions below the applicable standards, either for HC, for

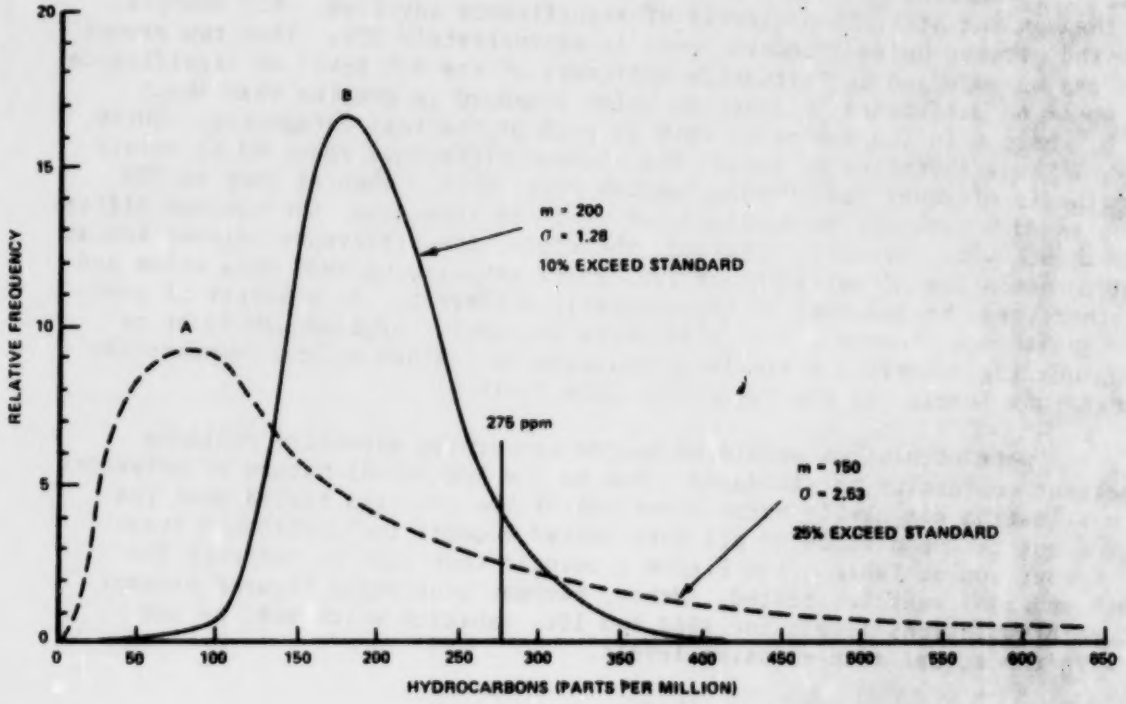
CO, or for both HC and CO. Next, results are expressed in terms of arithmetic mean and standard deviation and, finally, in terms of geometric mean and standard deviation. The rationale for this form of presentation is presented below and is elaborated upon in Appendix II.

The frequency distribution of automobile exhaust emissions is governed by constraints which make it unlikely that the emission measurements will follow a normal (Gaussian) distribution. In particular, emission concentrations are necessarily non-negative and are therefore strictly bounded on the low end of the distribution. At the high end of the distribution, however, emissions are not subject to such an arbitrary constraint. This fact, and the fact that errors of measurement tend to be proportional to the concentration being measured, combine to cause the frequency distribution of exhaust measurements to be skewed toward the high side of the range of emission values. Furthermore, experience as well as theoretical statistical arguments suggest that the frequency distribution of exhaust emissions is essentially log-normal. In other words, if the logarithms of the emission quantities are used to compile a frequency distribution or histogram, the resulting distribution tends to be symmetric and is approximated by a normal distribution with appropriate mean and standard deviation. These quantities, computed in logarithmic units, can be transformed back to anti-logarithms, but the transformed values are not to be confused with the mean and standard deviation computed from the original data as expressed in percent concentration, parts per million or grams per mile. Mean values computed from logarithmically transformed data represent geometric means, whereas mean values computed from the original data represent arithmetic means.

A word of explanation is in order with regard to the geometric mean and standard deviation and their interpretation in an emissions context. The geometric mean is in units of concentration or grams/mile, depending on whether the analysis deals with measurements expressed in concentration (as would be the case for 7-mode tests) or mass (as would be the case for CVS tests). The geometric standard deviation, however, is in reality a ratio and is accordingly dimensionless. If the geometric mean is multiplied by the geometric standard deviation, one obtains a quantity which represents approximately the 84th percentile of the distribution, in much the same way as one obtains this percentile in a normal distribution by adding the standard deviation to the mean. Similarly, by multiplying the geometric mean by the geometric standard deviation squared, one obtains approximately the 95th percentile of the distribution in much the same way as one obtains this percentile in a normal distribution by adding two standard deviations to the mean. In short, normal distribution probabilities can be employed directly in the statistical analysis of automobile exhaust emissions provided the geometric mean and standard deviation are used multiplicatively rather than additively.

The interpretation of automobile exhaust emission data and the conclusions drawn from these data depend strongly on the nature of the statistical analysis to which the data are subjected. Consequently, considerable care must be taken to prevent conclusions from being artifacts of the analysis and inappropriate to the purposes of the investigation. For example, consider the insert, which depicts two hypothetical distributions of hydrocarbon emissions in parts

per million (ppm). Distribution A has a lower geometric mean than Distribution B, but a greater fraction of the automobiles in Distribution B conforms to the standard than do those in Distribution A. The apparent anomaly occurs because of the considerably greater dispersion or scatter of emission measurements in Distribution A as compared with Distribution B. Thus, if the fraction of vehicles conforming to standards is the criterion of comparison, a different result is obtained than if attention is focused only on the difference between geometric means. For many purposes it is essential to take into consideration the entire statistical distribution of results rather than a single numerical index computed from that distribution.



HYPOTHETICAL EMISSION DISTRIBUTIONS

Finally, a note of caution must be injected concerning the purposes for which the arithmetic means and the geometric means are applicable. Inasmuch as the model distribution for emission measurements is taken to be log-normal, the mean and standard deviation of the log-transformed data for a particular vehicle category are estimates of the population parameters for that category. If these parameter estimates are known, the entire distribution can be approximated in a straightforward way. It must be pointed out, however, that the geometric mean is not appropriate for assessing the total contribution of a particular make of vehicle to the pollution inventory. For this purpose, the arithmetic mean is required. For example, the arithmetic mean, expressed in

grams per mile, can be multiplied by an estimate of the total mileage for a given class of vehicles to obtain an estimate of the "impact" of that class of vehicles on air quality. The geometric mean, on the other hand, would clearly be inappropriate for such estimation. It is for these reasons that the emission data contained in this report are presented in several different ways.

Figure 1 presents a graphic comparison of the aggregated emissions data for Kansas City and Houston in terms of the percent of the test fleet which exhibited emission levels below the standards set for CO and HC. It is evident from this figure that there is little difference between the two cities in this respect. This conclusion is based more on the magnitude of the differences observed than on the statistical levels of significance involved. For example, suppose the percent below standard level is approximately 50%. Then two groups of cars can be adjudged significantly different at the 95% level of significance if the observed difference in fraction below standard is greater than about $1.4/\sqrt{N}$, where N is the number of cars in each of the test categories. Quite clearly, if N is sufficiently large, the minimum difference required to reject the hypothesis of equal performance becomes very small. When as many as 500 vehicles in each category is involved, as it is in this case, the minimum difference is about 0.06. Strictly speaking, therefore, the difference between Kansas City and Houston for HC emissions of 1969 model vehicles exceeds this value and might, therefore, be regarded as significantly different. As a matter of practical significance, however, this difference is hardly large enough to be of much engineering concern. A similar conclusion is reached if one compares the mean emissions levels for the two cities (see Table 6).

A note of caution should be voiced concerning excessive reliance upon percent conforming to standards. Due to the log-normal nature of emissions data, a situation can easily arise where 50% of the vehicles tested meet the standards but the mean value of all cars tested exceeds the applicable standard. Comparison of Table 6 and Figure 1 reveals that such is the case for the 1968 and 1969 vehicles tested. Hence, percent conforming figures present a picture of emissions levels for 1968 and 1969 vehicles which must be tempered with the actual mean emission levels.

2.1.2 Results for 1970 Model Vehicles

Exhaust emissions data for each of the three principal effluents determined from measurements on 1970 model vehicles tested in six cities are shown in Tables 7 through 12. As before, the data are reported in terms of percent of vehicles below standards for CO, HC or both as well as in terms of means and standard deviations on both the arithmetic and geometric basis.

Figure 2 presents a graphic comparison of the six cities in terms of the percent of the test fleet which exhibited emission levels below the HC and CO standards. It is evident from this figure that the city of Denver departs markedly from the other five cities in this respect.

This observation is further substantiated by Table 13, in which the mean emission levels for the six cities are summarized. Again, only Denver stands out as distinct from the other cities. Finally, Figure 3 and Figure 4 present a graphical interpretation of both the Denver effect and the essential log-normal nature of emissions data. As is evident from comparison of both the HC and CO histograms for all cities except Denver and for Denver only, not only is the mean emission level higher in Denver but a substantially greater number of vehicles fail to pass emissions standards. In addition, histograms of the logarithms of the data are very nearly Gaussian distributions substantiating the log-normal nature of the data set. When Denver is considered alone, a smaller number of vehicles is available for analysis than in the case in which the data from several cities are pooled. This reduction in sample size results in a greater variation from a true Gaussian distribution. It should be reiterated at this point that conclusions reached from percent conforming figures should be tempered with actual mean emission levels. Even from this viewpoint, however, Denver's unique nature stands out, as is well evidenced by Figure 2 and Table 13.

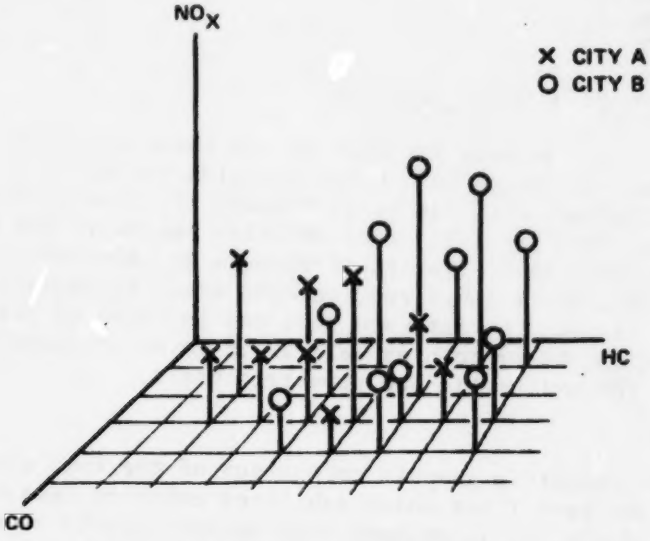
2.1.3 Results for 1971 Model Vehicles

Exhaust emissions data for each of the three principal effluents determined from measurements on 1971 model vehicles tested in four cities are shown in Tables 14 through 21. Tables 14 through 17, denoted Phase 1, summarize exhaust emission data for 1971 model vehicles tested in low mileage condition (less than 60 odometer miles). Tables 18 through 21, denoted Phase 2, summarize exhaust emissions data for "stabilized" engines after accumulation of approximately 5000 miles. Again, the data are reported in terms of percent of vehicles below standards for CO, HC or both as well as in terms of means and standard deviations on both the arithmetic and geometric basis.

Figure 5 presents a graphic comparison of the four cities in terms of the percent of the test fleet which exhibited emission levels below the HC and CO standards. Again, it is evident that Denver departs markedly from the other three cities, especially with regard to the low mileage vehicles. A similar conclusion can be drawn from Table 22, in which mean emissions for the vehicles tested in the four cities are compared for both low mileage and stabilized engines. The entire test fleet consisted of only 369 vehicles. Following mileage accumulation (4,000 to 7,000 miles), the same vehicles were retested on the presumption that the engines had stabilized. The principal effect of this stabilization on emissions is believed to be the result of "wearing-in" or "seating" of valves and piston rings as well as a stabilization of combustion chamber deposits.

In order to bring greater perceptiveness to bear on the nature of apparent differences between geographic locales and between makes and models, plots of emissions in various data subsets were employed. A hypothetical plot

of this type is shown in the insert. The three emittants are plotted along three coordinate axes, and the data for the two cities show up as two clouds of points in three-dimensional space. Plots of this type were found to be very useful in tempering conclusions drawn from statistical analyses based on means and standard deviations of data subsets. For example, it is very unlikely that two sets of data will be found without considerable intermingling of points, even though the means or "centers of gravity" of the two clouds are significantly different. By the use of discriminant function analysis, as presented in Appendix III, a derived plot can be evolved which maximizes the separation of data clouds and minimizes their overlap or interpenetration. It was on the basis of such plots, together with a consideration of the magnitude of differences among the means for the several cities, that Denver was isolated as the only city deserving especial note.



2.1.4 Summary of City and Vehicle Make Effects

It is often hazardous to ascribe differences observed in test results to one particular effect or another, inasmuch as several factors, inextricably involved, may be operating simultaneously. For example, the apparent difference in vehicle emissions noted for two cities may be confounded by the fact that there is a difference in the mean mileage levels between the two test fleets. There is also the possibility that the test fleets in the two cities are not statistically identical despite the fact that random selection techniques were used. Ideally, the same set of vehicles should be tested in different cities in order to measure city effects unconfounded with extraneous factors.

Another factor of import is the need to recognize the practical consequences of differences or effects determined by the application of statistical techniques. With a sufficient quantity of data (statistical degrees of freedom), a finding which is highly significant statistically can be ascertained,

but this finding may be of little practical importance to the air pollution problem. This point has been previously alluded to but is of sufficient importance to bear further elaboration.

Consider, for example, two categories of vehicles for which the arithmetic means of their hydrocarbon emissions are 200 ppm and 225 ppm. Assume that the standard deviation of emission measurements, as computed from measurements on individual vehicles, is 60 ppm. The standard error of the difference between means is approximately 85 ppm/ $\sqrt{N}$, where N is the number of vehicles tested in each category. By standard statistical argument, a difference between the observed means of the two categories is adjudged significant at the 5% significance level if the observed difference is approximately twice as large as the standard error of the difference. In the present instance, this event occurs if 170 ppm / $\sqrt{N}$ is less than 25 ppm, the observed difference between the two vehicle categories. Quite clearly, therefore, whether the difference is declared statistically significant depends on the number of vehicles tested. If N is greater than about 46, the observed difference of 25 ppm would be declared to be "statistically significant", whereas it would not be regarded as significant if N is smaller than 46, say 35.

It is clear, therefore, that by pooling a sufficient amount of data it is possible to label as statistically significant an effect which may be of negligible engineering magnitude. More germane is the consideration that if the difference between two means is no greater than--say--10% of their pooled mean, it may be of little consequence, for purposes of air quality assessment, to regard the two quantities as distinct. Moreover, the importance of an effect does not depend on the number of vehicles tested, and the mere act of declaring the effect to be statistically significant in no way augments its practical magnitude.

It is this philosophy which governs many of the decisions made in this report, particularly as they apply to the pooling of data from various source categories, such as makes, models and cities. For example, it is this type of consideration which draws special attention to Denver and causes it to be treated separately from other cities in the statistical analysis. Though statistically significant differences in mean emission levels can be established among at least some of the other cities, these differences are not large enough to merit separate statistical treatment. For this reason, it is regarded logical to pool results for all cities other than Denver. Moreover, a physical reason, namely altitude, can be advanced for the "Denver effect" and is believed to be a substantive constraint affecting the compliance of that city with emission standards. Though Los Angeles shows some tendency to lower emissions than the other cities, this difference is not of sufficient magnitude to affect the pooled average appreciably. Accordingly, it was considered legitimate to pool Los Angeles with the other cities, Denver excluded. The ability to pool the data, however, does not preclude the desirability of sampling from several cities in the interest of obtaining a more representative and credible cross section of in-use vehicles.

Table 23 summarizes the salient features of the seven-mode tests of 1968-1971 model vehicles. City effects on emissions were observed only for 1970 and 1971 model year vehicles, since a wider segment of the geographical area of the United States was included in the surveillance program associated with these models. Although a number of statistically significant effects can be shown to occur in one city or another or for one effluent or another on an isolated basis, only two consistent effects associated with cities predominate.

The first of these is a strong effect associated with Denver, which in all test data for all vehicles yielded a significantly higher value for HC and CO emissions than was observed in the other cities and, as might be expected, a tendency toward lower NO_{xc}. The principal consideration distinguishing Denver is its altitude, which affects carburetion and tends to produce an excessively rich fuel mixture. The second effect is that associated with Los Angeles. Emission data for this city in general show HC and CO emission levels somewhat lower than for the other cities tested, and NO_{xc} emissions somewhat higher than in some other cities with relatively high HC and CO levels. It should be noted that in addition to small differences in mean emission levels, discriminant plane analysis (Appendix II) and plots of the emission data were used to determine this small Los Angeles effect. As has been pointed out, however, the Los Angeles effect was not considered strong enough to justify special treatment of the data.

City effects associated with NO_x are greatly reduced when the humidity correction is applied to the data to obtain the NO_{xc} levels as used in this report. This fact substantiates the effectiveness of the humidity correction in minimizing data variations associated with tests conducted under different ambient conditions.

Tables 24 and 25 summarize emissions for 1968 and 1969 model year vehicles according to engine CID for all cases in which at least thirty units were available for averaging. The averages are taken over the two cities in which tests were conducted, namely Kansas City and Houston. These tables show that appreciable differences occur among engines but that these differences are not solely related to size but rather to design. Both low and high emitters can be found among both small and large CID engines. In addition, generalizations are further complicated by the fact that NO_x emissions often tend to be inversely related to CO and HC emissions, so that it is difficult to make broad statements with regard to total emissions.

Data were also available for comparison of 1970 model vehicles by engine size. Table 26 presents those cases in which a sufficient number of vehicles was available to justify comparisons and represents aggregation of data from Houston, Los Angeles, and Detroit. Table 27 presents similar data for Denver. In this table, however, it was necessary to reduce the minimum number of test units to 10 rather than 30 in order to obtain averages for comparison of engine size.

Comparison of emissions according to vehicle make involved the pooling of many sizes of engines within the make, as shown in Table 28. In view of

this fact, apparent differences among makes must be viewed with caution, and any attempt to rank makes in a strictly monotonic sequence should be resisted. This caution stems largely from the interrelation among statistical significance, number of vehicles tested, and variability of emission measurements, as previously noted.

As an illustration of this point, consider the following example, drawn from 1971 model year vehicles as tested in Phase 1 in Denver (Table 17).

Make	N	HC Emissions (gms/mi) Mean	Std. Dev.
Cadillac	3	0.67	0.18
Pontiac	5	1.82	0.17
Buick	9	2.08	0.99
Oldsmobile	6	2.13	0.91
Chevrolet	34	2.37	0.55
Volkswagen	23	2.43	0.64
Plymouth	14	2.99	0.72
Ford	24	3.12	1.19
American	20	3.12	1.27
Dodge	3	4.33	1.69

The difference between Pontiac and Chevrolet (0.55 gms/mi) is statistically significant. However, the difference between Pontiac and Dodge (2.51 gms/mi), although of greater apparent magnitude, is not adjudged to be statistically significant because of the small number of Dodge vehicles tested and the large standard deviation which they exhibit. Thus it is clear that unless ranking is tempered with much statistical and engineering judgment, spurious conclusions may result.

2.1.5 Mileage Effects

The term "mileage effects" when used with reference to emissions may have several connotations and may therefore be subject to misinterpretation. Ideally an investigation of "mileage effects" should only be concerned with the deterioration of emission control performance with increasing mileage. Practically, however, a variety of factors such as the state of engine adjustment or repair hinder any attempt to isolate this fundamental mileage effect. Emittant levels were established for each vehicle in an "as received" condition regardless of its operating condition. Consequently, in the context of this report, mileage effects will be used in its broadest sense to describe trends which become increasingly prominent as the vehicle accumulates mileage or receives inadequate maintenance.

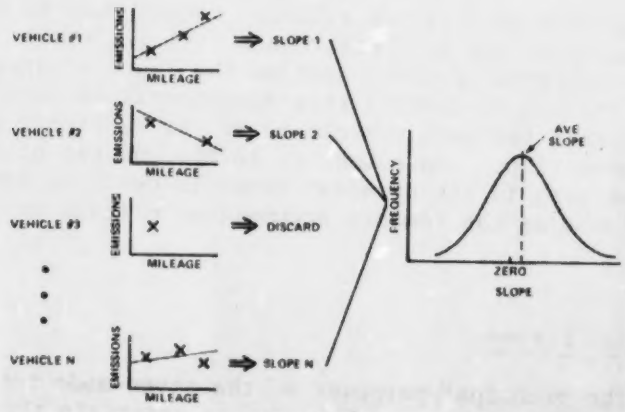
2.1.5.1 Stabilized Engines

One of the principal purposes of the seven-mode test program on 1968-1969 vehicles in Houston and Kansas City was to ascertain the presence and mag-

nitude of a mileage effect by performing three emissions measurements on each vehicle candidate: an initial test (Phase I), a subsequent test after approximately 4,000 miles (Phase II), and a final test after an additional 4,000 miles (Phase III). The initial tests were performed on well-stabilized engines, the mean mileage for all vehicles tested during Phase I being approximately 28,000 miles for 1968 and 17,000 miles for 1969 model vehicles.

Two distinct approaches to analysis of the mileage effect are possible. The first approach consists basically of pooling all the emissions data and performing a linear regression vs mileage. Data from over 1600 applicable emission tests were processed and these pooled data showed a general trend of increasing HC and CO (approximately 0.5 to 1.0% per 1000 miles) with a similarly decreasing trend in NO_x.

Such an approach based upon pooled data, however, can frequently mask several important facets of the "mileage effect", since the analysis provides only an overall result and cannot yield the underlying distribution derived from each individual vehicle. In addition, many vehicles could not be retrieved for Phase II or Phase III and hence could not contribute any information with regard to change of emissions with mileage. Though it can be argued that different vehicles tested at different mileages make possible the inference of mileage trends, these trends are confounded with numerous other factors which differentiate one vehicle from another, such as maintenance and driving habits. To avoid these problems, a new analysis was undertaken which performed an emissions vs mileage regression for each candidate vehicle which survived more than one test. This set includes vehicles which were available during all three phases, Phase I and II or Phase I and III. The resultant trends (slopes) were then averaged and the result tested using a standard t-test at both 95% and 99% significance levels to determine if the average slope was significantly different from zero. In addition, a histogram of the individual vehicle slopes was plotted to gain more insight into the nature of the mileage effect process. A schematic diagram of the general technique used is presented in the insert for a hypothetical case.



FLOW DIAGRAM FOR COMPUTATION OF MILEAGE EFFECTS

A summary of the significant results for 1968 and 1969 data is presented in Table 29. Examination of this table reveals a mileage effect of comparable magnitude to that found using a pooled vehicle technique and including non-survivors. A major advantage of the individual surviving vehicle technique rests in the information provided by the histograms of the individual slopes. Figures 6 and 7 illustrate typical distributions of slopes characteristic of 1968 and 1969 data. It should be noted that data for these years represent well stabilized engines with accumulated mileage over 20,000 miles and therefore would not be expected to exhibit dramatic mileage effects. For these particular data sets, the distributions appear almost equally spaced on both sides of zero. This phenomenon is demonstrated in Table 29 for the case of HC in 1969. Due to the large sample size of 318 vehicles, the standard t-test provides a 95% confidence level that the mean mileage effect is different from zero. In this particular case, HC deteriorates 0.98% per 1000 miles. The percentage is computed by dividing the slope (emission increment per 1000 miles) by the extrapolated emission levels at 4000 miles. This mileage point was chosen as a base since it corresponds to a new but stabilized engine.

Several interpretations of this result are possible. If one is primarily interested in impact studies in which large numbers of vehicles are being considered and mean values are important, this increase in HC is most probably significant. On the other hand, little can be said about the performance of an individual vehicle due to the wide dispersion exhibited by the slopes. A similar phenomenon exists in virtually all other data sets in which a mileage effect can be established. No doubt factors such as maintenance practice, grade of fuel, and other unknowns confound the mileage phenomenon. For example, a tune-up immediately before testing in Phase II or Phase III could override or mask normal mileage deterioration. In summation, although a statistically significant mileage effect can be shown in many data sets, care should be exercised in the interpretation and use of this data.

2.1.5.2 Low Mileage Versus Stabilized Engines

To explore the possibility that mileage effects on emissions may exhibit different characteristics at different stages of the mileage accumulation life of a vehicle, emissions data were collected on a fleet of 1971 models when new (less than 60 miles) and on the same vehicles after they had gone at least 4,000 miles but less than 7,000 miles. Emissions data for each of 369 vehicles were regressed against mileage and the individual emissions vs mileage trends were pooled in the manner described above. These results are presented in Table 30 for each of the four cities investigated and for all cities combined except Denver. In contrast to the findings for 1968-1969 vehicles having higher accumulated mileages, HC, CO, and NO_x during 1971 tests were found to increase by several percentage points per 1,000 miles in all cities except Denver, where a 7.5% decrease in CO and a 2.0% increase in NO_x were observed. Although the precise cause of this phenomenon is unknown, special carburetor adjustments and other tune-up procedures unique to Denver's

high altitude may well be a factor. In terms of absolute emissions levels the change in emissions per 1,000 miles is usually considerably greater for vehicles with initially low mileage than for vehicles with initial mileage in the 20,000 to 30,000 mile range. Figure 8 presents slope histograms for all cities pooled except Denver. Figure 9 presents corresponding histograms for Denver only. These histograms are comparable to Figures 6 and 7 for 1968 and 1969 models but show a much more appreciable mileage effect.

Tables 31 and 32 present mileage effects by make for the low mileage vs stabilized engine data base. In these tables, only those makes are included which reach significance at at least the 95% level. Table 31 is a composite of all the 1971 data excluding Denver, whereas Table 32 contains data for Denver only. Appreciable differences among makes with regard to mileage effects are observed in these tables.

2.2 CVS TESTS OF 1957-1971 MODEL VEHICLES

This section of the report summarizes results from a single test program devoted to the measurement of exhaust emissions from 1957 through 1971 model light-duty vehicles in six metropolitan areas. Separate treatment is afforded these results since, due to the unique orientation and objectives of this program, test procedures for emissions measurements were employed which produced numerical data not readily comparable to those discussed in Section 2.1. In addition, modal emissions data and evaporative emissions data are also presented.

A brief overview of the program is given in Table 33. The principal function was the collection of data from which average emission factors could be formulated in order to define the contribution of the automobile population to the nations' air pollution burden. To achieve this objective, the best available methodology and technology was employed to accurately determine mass emissions under vehicle operating conditions representative of road use. Since 1957-1971 model vehicles comprised more than 95% of the population as of 1971, a statistically-representative sample of this population was tested in each of the six cities which were chosen to maximize variations in climate, terrain, and urban development.

Fifteen makes and/or manufacturers were identified. Since fifteen model years were also involved and a city vehicle fleet consisted of only approximately 170 units, the situation which occurred most frequently was that only one sample of any one make/model year was tested. Consequently to ascertain differences among model years or makes, data aggregation by all vehicles within a make or by manufacturer was necessary. In addition, any one city sample did not necessarily include all model years for each make or all makes themselves. In the case of the early-year models (1957-1960) with a relatively small population compared with the late-year models, only two or three makes (one vehicle

each) were tested within any one city. Thus, the sample size for any one make/model year/city category was very small at best and frequently consisted of only a single datum point or frequently no data at all. Despite these limitations in the actual size of the sample, the overall sample is very representative of the overall vehicle population on the road. Data from this program are particularly useful, therefore, in estimating the overall impact of emissions on air quality.

2.2.1 Emissions Data and Results

As in the previous programs, all vehicles were tested for exhaust emissions in an as-received condition. Cold start tests, with only minor exceptions, were performed in accord with the 1972 (CVS-C) and 1975 (CVS-CH) Federal Test Procedures (FTP). In actuality, however, only one test per vehicle was made, since vehicle-diluted exhaust emissions were bagged in such a manner that vehicle mass emissions could be calculated according to both 1972 and 1975 specifications. In addition to an assessment of the three principal exhaust gas pollutants, a measurement was also made of carbon dioxide (CO_2).

In programs concerned with certification and compliance, the emissions tests are performed using a specified blend of fuel (indolene) in the vehicle. Since the goal of this effort was to define the actual emissions of vehicles as operated on the road, whatever fuel was in the vehicle tank was used in all cases (supplemented by a commercial fuel as required).

Mass emissions data, expressed as arithmetic and geometric means as well as their respective standard deviations, are summarized in Tables 34 and 35 for the 1972 FTP, and in Tables 36 and 37 for the 1975 FTP. In addition, the percentage of vehicles with emission levels below the reference levels of 3.4 gms/mi HC, 39.0 gms/mi CO, and 3.0 gms/mi NO_{xc} is also presented. Although these reference levels do not represent emission standards under which the vehicles were certified, they are useful in examining time trends for vehicles of various model years in which no standards or differing standards were in effect. The results are aggregated by year and by all cities except Denver and Denver only.

The differences that are inherent in the 1972 and 1975 procedures reflect the fact that not all trips made by a vehicle originate from a "cold start" (defined in the Federal Register as a start preceded by a 12-hour, no-use soak period). The 1972 FTP determines mass emissions from a driving schedule (LA-4) that comprises two portions, a cold-transient and a cold stabilized. The 1975 FTP uses the same driving schedule but also adds a "hot start" hot transient portion. In this latter case, emissions are determined by combining a weighted average of the cold and hot-transient portions with the cold-stabilized portion. Since a large fraction of the composite HC and CO emissions are generated during the fuel-rich, engine warm-up phase of the cold-transient portion of the driving schedule, the 1975 data (as compared with the 1972 data) will show lower levels of emission for these two effluents.

The data of Tables 34 through 37 bear out this conclusion. On the other hand, NO_{xc} levels remain substantially uniform, the observed differences probably being attributable to experimental sources.

Trends by model year in mean emission levels and percentage of vehicles below the reference levels are well defined for all effluents. HC and CO levels show continuing decreases and reflect the impact of increasingly more stringent emission controls. Consistent with this decrease, there is observed an increase in NO_{xc} levels which, during this period of time, were not subject to control. Figure 10, which presents 1975 CVS emission levels vs the cumulative percentage of test vehicles, emphasizes these model year trends for the three pollutants.

Table 38 summarizes emissions data for pre-control and control time periods by geographic allocation. As in the case of the 7-mode test data, emissions data taken in Denver were found to be clearly different from those obtained in the five other cities. Consistent with previous findings, high levels of HC and CO emissions were measured with correspondingly low levels of NO_{xc} for reasons which have already been discussed. Consequently, the Denver data were considered separately from the other cities, Los Angeles, Chicago, Houston, St. Louis and Washington, D.C.

Table 39 presents the data by vehicle weight class as determined from the vehicle weight classification specified by the Federal Test Procedures. Five hundred pound increments were used to establish classes from 1500 to 5500 pounds. An increase in NO_{xc} levels with weight is evident but trends in HC and CO are not as clearly defined.

2.2.2 Modal Emission Sequence

Considerable interest in recent years has centered around the development of computer models to describe emission levels during various phases of vehicle operation. For example, minimization of vehicle emissions could well become a significant consideration in the design of expressway entrance and exit ramps and in other highway design applications. For such purposes, it is necessary to model the impact of emissions as they occur in the situation of interest. Such modelling can be achieved if there are available emission factors for a variety of steady states and driving modes. With these potential applications in mind, a survey of the driving characteristics of the public in the Los Angeles area was undertaken and a profile of average acceleration/deceleration rates were established for use as transitions between all paired combinations of the following speeds: 0 mph, 15 mph, 30 mph, 45 mph and 60 mph. In addition, acceleration/deceleration rates both higher and lower than the average values were used as transitions only between all paired combinations of 0 mph, 30 mph, and 60 mph. A total of 32 accel/decel modes was developed.*

* "The Construction of Chassis Dynamometer Test Cycles," Vols. I and II, Scott Research Laboratories, Inc., 1971, San Bernadino, California.

A driving cycle comprised of a sequence of the 32 accel/decel modes with the transitions consisting of short steady-state idles or cruises was identified. The complete sequence defined a driving schedule of 1054 seconds duration. Emissions data obtained from vehicles operated over this driving schedule were compared with composite results calculated from the emissions data corresponding to the individual steady-state and accel/decel modes which comprise this driving schedule. The synthesized composite mass emissions calculated in this manner agreed very well with those measured by actual operation of the vehicle over this driving schedule. There is encouragement, therefore, to presume that realistic composite emissions for different driving schedules formulated from various combinations of steady-state and accel/decel modes can be accurately synthesized.

Table 40 lists modes together with the corresponding time in mode, average speed, average accel/decel rate, and distance traveled. Emissions data, taken with the constant volume sampling (CVS) technique, were acquired for each of these 32 modes. Table 41 summarizes the results for HC, CO, CO_2, and NO_x for all cities except Denver, and Table 42 shows comparable data for Denver alone.

To provide useful information on the emissions from vehicles operating at cruise (steady state) conditions, data were collected at speeds of 0 (idle), 15, 30, 45 and 60 mph. CVS techniques again were used in the acquisition of these emissions data. The results are shown in Table 43. With minor differences, HC and CO mean mass emissions at 30 mph, 45 mph and 60 mph are relatively uniform in all cities. Sizable increases in the levels of CO_2 and NO_x emissions occur as the steady-state speed increases from 30 mph to 60 mph. The 15 mph cruise is identified by unusually high levels of HC, CO and CO_2 as compared with the 30 mph cruise condition.

2.2.3 Evaporative Emissions

The venting of fuel vapors from the carburetor front chamber and vehicle fuel tank constitutes a sizable source of HC emissions in the absence of appropriate control devices. A determination of the mean evaporative losses was made for a randomly-selected subset of vehicles in Los Angeles and Denver. These tests were conducted in accord with the requirements of SAE Procedure J171 and constitute the SHED (Sealed Housing for Evaporative Determinations) technique. Briefly, two types of losses are measured while the vehicle is enclosed in the SHED, those associated with the diurnal soak and with the hot soak. The former involves losses occurring over a one-hour period while fuel (in the vehicle tank) is raised in temperature as per a prescribed schedule. The latter involves losses, also over a one-hour period, while the vehicle cools following the completion of a complete cold-start 1975 Federal Test Procedure.

A word of explanation is in order with regard to the interpretation of evaporative emissions as measured by the SHED technique. Federal certification values, based on the canister technique (SAEJ170), are generally considerably

lower than emissions as measured by the SHED procedure. The canister method is aimed at collecting and weighing diurnal losses, running losses and hot soak losses from the fuel tank and other parts of the fuel system. The SHED technique takes account of emissions from the entire fuel system including emissions, such as gasket leakages, that would be hard to trap. Consequently, evaporative emissions determined by the SHED technique are not directly comparable to those determined by the Federal procedure.

For purposes of the surveillance program, it was advantageous to employ the SHED rather than the canister technique in conducting evaporative emissions tests on 1957 to 1971 model vehicles. Vehicles manufactured prior to the implementation of evaporative controls are not readily amenable to measurement by the canister system because of the multiplicity of tubes and connections which would have been required to recover the emissions from diverse fuel systems. On the other hand, the SHED technique, being performed in a sealed enclosure, could accommodate the wide variety of vehicles involved and was felt to be the only reasonable approach by which pre-control and later model year vehicles could be compared. Moreover, most of the vehicles in the 1957-1971 model years belonged to the pre-control category: only 1971 model year vehicles and 1970 model year vehicles from California employed evaporative controls. In addition to providing a uniform system for comparing all vehicles in the program, the SHED technique was also regarded as providing a realistic assessment of overall evaporative emissions from the standpoint of their impact on air quality.

Evaporative emissions for Los Angeles and Denver vehicles are summarized below. A commercially-available, popular, premium-grade fuel was used for these tests.

	Los Angeles	Denver
Number of Vehicles	126	20
Diurnal Soak, (HC, grams/test)	23.67	47.20
Hot Soak (HC, grams/test)	13.75	34.78
Combined Losses (HC, grams/test)	37.41	81.98
Mean Differences Between Replicates*		
Diurnal Soak (HC, grams/test)	3.99	13.80
Hot Soak (HC, grams/test)	0.27	18.08
Combined (HC, grams/test)	0.01	31.88

* Ten replicates on Los Angeles, only one in Denver.

Based on the data means, the diurnal losses are appreciably larger than the hot soak losses with the Denver losses approximately twice as large as those in Los Angeles. In addition, a year-by-year breakdown from 1957 to 1971 of the diurnal, hot soak and combined means for the Los Angeles data is presented in Table 44 and summarized below.

MEAN LOS ANGELES EVAPORATIVE EMISSION LEVELS USING SHED TECHNIQUE

	HC - gm/test	
	Pre-Control	1970-1971
Diurnal Mean	25.97	16.28
Hot Soak Mean	14.67	10.92
Combined Loss	40.64	27.20

Although no dramatic trend exists, evaporative losses as measured by the enclosure technique show smaller evaporative losses for 1970 and 1971 Los Angeles vehicles employing evaporative control devices than for pre-control vehicles in that city.

EXPLANATION OF TABLES

Table 1 is a summary of the Surveillance Programs employing the 7x7 Federal Test Procedure.

Tables 2 through 5 present vehicle emissions as determined by 7x7 Federal Test Procedure by manufacturer and make. N denotes the number of vehicles tested, and the average mileage for those vehicles is given, in thousands of miles, in the column headed "Mean Miles (K)". The percent of vehicles which exhibited emission levels within the applicable standard levels set for hydrocarbons (HC), carbon-monoxide (CO) and for both HC and CO are given together with arithmetic and geometric means and standard deviations. In some vehicle categories, there were missing observations for one or more of the emittants. The tabulated value of N does not reflect this fact, but it is taken into account in the computed means and standard deviations.

Table 6 is self-explanatory.

Tables 7 through 12 follow the same format as Tables 2 through 5. Data were obtained using the 7x7 Federal Test Procedure.

Table 13 is self-explanatory.

Tables 14 through 21 are similar to Tables 2 through 5 except that in the Phase I tables the mean mileage is expressed in miles rather than in thousands of miles. All data were obtained using the 7x7 Federal Test Procedure.

Tables 22 through 32 are self-explanatory.

Table 33 is a summary of Six City Surveillance Program. All data presented for this program (Tables 34 through 39) were obtained using the 1972 CVS-1 and 1975 CVS-3 tests.

Tables 40 through 44 are self-explanatory.

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Table 1

SUMMARY OF 7-MODE SURVEILLANCE PROGRAMS BY VEHICLE MODEL YEAR

	1968-1969 MODEL VEHICLES	1970 MODEL VEHICLES	1971 MODEL VEHICLES
OBJECTIVES:	EVALUATE MILEAGE AND CITY EFFECTS; DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS	DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS; EVALUATE CITY EFFECTS	DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS; EVALUATE CITY EFFECTS, COMPARE LOW MILEAGE AND STABILIZED ENGINE EMISSIONS (PAIRED TESTS).
BASIC TEST PROCEDURES:	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 31, NO. 61 (PART II), MARCH 30, 1966; EACH VEHICLE TESTED 3 TIMES, INITIALLY AND AT EACH OF TWO 4,000-MILE INTERVALS.	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 33, NO. 108, JUNE 4, 1968 (PART II); EACH VEHICLE TESTED ONCE (MINIMUM MILEAGE REQUIREMENT 4,000 MI.).	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 33, NO. 108, JUNE 4, 1968 (PART II); TWO PAIRED TESTS PER VEHICLE: LOW MILEAGE ENGINE (49 MILES) AND STABILIZED ENGINE (4,000-7,000 MILES).
INSTRUMENTATION:	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.
CITIES:	KANSAS CITY AND HOUSTON	KANSAS CITY, HOUSTON, LOS ANGELES, DETROIT, DENVER, WASHINGTON	HOUSTON, LOS ANGELES, DETROIT AND DENVER
EMISSION STANDARDS:	275 ppm HC, 1.50% CO (410 ppm HC, 2.30% CO FOR VW)	2.2 GRAMS/MI. HC, 23.0 GRAMS/MI CO	2.2 GRAMS/MI. HC, 23.0 GRAMS/MI. CO.
TOTAL VEHICLES TESTED:	1949	2181	389

TABLE 2
EMISSION LEVELS FOR 1968 MODEL VEHICLES
KANSAS CITY

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	18	22.4	28	33	17	337.	119.	319.	1.40	2.30	1.28	1.91	1.97	1536.	716.	1366.	1.68
CHRY CORP	68	36.6	44	19	13	333.	254.	298.	1.49	2.12	0.91	1.95	1.51	1587.	573.	1492.	1.41
PLYM	33	35.6	48	27	21	282.	88.	271.	1.34	1.73	0.53	1.65	1.41	1503.	484.	1509.	1.38
DODGE	17	37.8	59	0	0	303.	135.	285.	1.40	2.42	1.06	2.25	1.45	1494.	831.	1202.	2.14
CHRY	18	37.1	22	22	11	454.	448.	372.	1.71	2.53	1.06	2.31	1.57	1689.	419.	1630.	1.34
FORD MO CO.	86	33.0	47	55	30	304.	85.	295.	1.27	1.83	1.28	1.52	1.84	1589.	617.	1421.	1.73
FORD	79	33.3	47	53	32	306.	88.	296.	1.28	1.87	1.32	1.54	1.88	1604.	614.	1437.	1.73
MERC	7	29.1	43	71	14	288.	49.	285.	1.18	1.38	0.41	1.33	1.30	1417.	678.	1255.	1.75
LINC	0	0.0	0	0	0	0.	0.	0.	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.0
GM	276	31.8	50	29	22	301.	131.	279.	1.46	2.09	1.05	1.87	1.61	1282.	406.	1199.	1.52
CHEV	136	29.4	32	27	17	345.	142.	321.	1.46	2.21	1.23	1.96	1.63	1267.	443.	1155.	1.67
PONT	38	30.6	74	50	42	238.	62.	229.	1.33	1.54	0.47	1.45	1.50	1349.	287.	1319.	1.24
OLDS	37	31.6	70	24	24	268.	125.	250.	1.41	1.92	0.73	1.76	1.60	1176.	233.	1151.	1.25
BUICK	44	36.6	50	2	2	297.	116.	282.	1.35	2.67	0.80	2.56	1.34	1245.	443.	1167.	1.45
CADI	21	39.5	90	62	57	197.	59.	189.	1.35	1.37	0.36	1.30	1.43	1525.	415.	1458.	1.39
VOLKS	50	31.1	56	66	44	426.	211.	384.	1.57	1.90	0.90	1.67	1.75	1313.	434.	1239.	1.43
TOTAL	498	32.2	48	36	24	320.	160.	295.	1.46	2.04	1.07	1.80	1.68	1389.	506.	1277.	1.58

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

TABLE 3
EMISSION LEVELS FOR 1968 MODEL VEHICLES
HOUSTON

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	23	35.0	13	30	9	355.	148.	338.	1.33	1.98	1.00	1.76	1.67	1265.	382.	1175.	1.60
CHRY CORP	83	40.3	34	28	14	376.	307.	328.	1.56	2.37	1.49	2.01	1.78	1264.	538.	1078.	1.91
PLYM	29	39.9	48	41	21	381.	256.	330.	1.65	1.88	1.30	1.55	1.87	1399.	574.	1232.	1.84
DODGE	29	43.7	24	34	21	396.	434.	327.	1.62	2.19	0.97	1.98	1.59	1257.	524.	1131.	1.67
CHRY	25	36.7	28	4	0	349.	152.	320.	1.42	3.14	1.89	2.75	1.64	1041.	458.	866.	2.20
FORD MO CO.	75	37.5	48	55	33	317.	193.	288.	1.49	1.70	1.07	1.42	1.84	1477.	657.	1311.	1.70
FORD	70	37.0	49	51	33	319.	199.	288.	1.53	1.75	1.08	1.47	1.83	1480.	677.	1304.	1.73
MERC	5	44.9	40	100	40	293.	77.	285.	1.31	0.96	0.35	0.89	1.60	1439.	324.	1405.	1.30
LINC	0	0.0	0	0	0	0.	0.	0.	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.0
GM	249	35.9	47	25	18	367.	363.	310.	1.64	2.16	1.25	2.07	1.70	1030.	462.	927.	1.62
CHEV	115	35.9	31	30	18	473.	503.	377.	1.82	2.43	1.46	2.04	1.85	1049.	533.	909.	1.76
PONT	43	32.4	70	37	33	250.	51.	245.	1.23	1.83	1.00	1.65	1.54	1182.	515.	1078.	1.58
OLDS	39	33.8	44	13	8	318.	138.	296.	1.45	2.34	1.18	2.29	1.62	876.	363.	800.	1.57
BUICK	42	40.0	61	5	5	271.	50.	266.	1.20	2.66	0.80	2.53	1.38	969.	228.	942.	1.27
CADI	10	42.5	80	50	50	240.	179.	205.	1.69	1.97	0.93	1.81	1.92	1055.	284.	1023.	1.31
VOLKS	39	31.5	46	59	44	671.	680.	486.	2.09	2.48	1.88	1.88	2.16	942.	453.	800.	1.91
TOTAL	469	36.5	43	33	22	385.	372.	323.	1.66	2.25	1.34	1.91	1.80	1145.	534.	1008.	1.74

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

TABLE 4
EMISSION LEVELS FOR 1969 MODEL VEHICLES
KANSAS CITY

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	19	20.1	16	47	5	383.	162.	358.	1.44	1.36	0.56	1.22	1.67	1964.	381.	1928.	1.22
CHRY CORP	82	21.2	49	37	26	328.	209.	300.	1.45	2.04	1.05	1.79	1.68	1613.	500.	1515.	1.47
PLYM	28	21.5	57	36	29	293.	94.	282.	1.31	1.75	0.58	1.65	1.44	1880.	353.	1841.	1.25
DODGE	30	22.4	40	27	17	337.	130.	317.	1.41	2.51	1.27	2.18	1.76	1366.	553.	1240.	1.61
CHRY	24	19.3	50	50	33	399.	345.	301.	1.64	1.80	1.02	1.55	1.75	1609.	426.	1550.	1.34
FORD MO CO.	113	21.6	43	62	35	322.	261.	292.	1.44	1.45	0.72	1.30	1.61	1728.	509.	1640.	1.42
FORD	97	23.1	38	57	28	332.	280.	299.	1.46	1.55	0.73	1.39	1.60	1722.	530.	1625.	1.44
MERC	16	12.7	75	94	75	261.	64.	255.	1.24	0.89	0.29	0.85	1.35	1769.	365.	1733.	1.24
LINC	0	0.0	0	0	0	0.	0.	0.	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.0
GM	249	21.0	65	31	29	269.	123.	251.	1.42	1.98	0.97	1.80	1.54	1425.	404.	1345.	1.48
CHEV	90	20.7	49	21	19	307.	171.	280.	1.49	2.10	0.92	1.95	1.44	1392.	427.	1314.	1.45
PONT	77	21.7	65	34	29	270.	74.	262.	1.29	1.85	0.71	1.72	1.50	1484.	344.	1437.	1.31
OLDS	41	19.1	78	27	27	241.	77.	230.	1.36	2.25	1.46	1.95	1.68	1286.	442.	1137.	1.89
BUICK	27	24.2	78	37	37	235.	65.	226.	1.34	1.99	0.79	1.83	1.56	1501.	361.	1457.	1.29
CADI	14	17.6	100	86	86	164.	42.	160.	1.27	1.17	0.36	1.11	1.42	1578.	426.	1518.	1.35
VOLKS	31	18.2	81	94	77	321.	210.	273.	1.74	1.30	0.63	1.11	1.88	1674.	512.	1607.	1.33
TOTAL	494	20.9	56	44	32	299.	187.	273.	1.47	1.81	0.94	1.60	1.65	1562.	476.	1472.	1.47

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

TABLE 5
EMISSION LEVELS FOR 1969 MODEL VEHICLES
HOUSTON

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	13	19.6	38	54	15	301.	58.	296.	1.21	1.52	0.62	1.38	1.59	1574.	379.	1530.	1.29
CHRY CORP	73	25.5	49	36	29	294.	94.	281.	1.36	2.04	1.07	1.77	1.73	1373.	584.	1240.	1.61
PLYM	34	25.8	38	29	21	305.	76.	294.	1.33	2.31	1.15	2.02	1.73	1424.	659.	1261.	1.69
DODGE	23	24.9	57	39	35	276.	62.	269.	1.24	1.71	0.70	1.55	1.61	1531.	523.	1429.	1.50
CHRY	16	26.0	63	44	38	298.	154.	270.	1.54	1.92	1.25	1.62	1.84	1045.	355.	983.	1.46
FORD MO CO.	105	25.9	30	49	22	354.	164.	326.	1.48	1.75	0.85	1.56	1.61	1405.	518.	1287.	1.58
FORD	99	26.1	29	51	23	357.	168.	327.	1.49	1.65	0.75	1.50	1.57	1438.	491.	1342.	1.49
MERC	6	22.7	33	17	0	306.	48.	303.	1.16	3.31	0.99	3.14	1.48	777.	681.	593.	2.25
LINC	0	0.0	0	0	0	0.	0.	0.	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.0
GM	268	25.8	57	33	28	271.	105.	255.	1.40	1.95	0.86	1.78	1.55	1290.	428.	1203.	1.51
CHEV	114	27.1	49	36	29	291.	122.	274.	1.42	1.86	0.77	1.70	1.55	1277.	465.	1187.	1.49
PONT	65	29.7	38	20	13	311.	94.	300.	1.30	2.13	0.94	1.96	1.52	1374.	435.	1265.	1.63
OLDS	32	24.6	69	34	34	235.	56.	228.	1.29	2.00	0.83	1.82	1.56	1211.	360.	1157.	1.37
BUICK	31	19.9	81	10	10	243.	35.	240.	1.16	2.41	0.96	2.26	1.44	1170.	384.	1082.	1.60
CADI	26	18.4	100	77	77	156.	21.	155.	1.14	1.31	0.39	1.26	1.32	1367.	326.	1323.	1.32
VOLKS	29	25.1	52	69	45	498.	334.	445.	1.52	2.10	1.24	1.85	1.64	1335.	400.	1212.	1.83
TOTAL	488	25.6	49	39	28	306.	152.	283.	1.46	1.92	0.92	1.72	1.60	1337.	473.	1234.	1.56

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

Table 6

SUMMARY OF EMISSIONS (ARITHMETIC MEANS)
FOR 1968 AND 1969 MODEL VEHICLES

	HYDROCARBONS		CARBON MONOXIDE		NO_{x_c}	
	ppm	gm/mi	Percent	gm/mi	ppm	gm/mi
1968 MODEL VEHICLES						
KANSAS CITY	320	3.81	2.04	46.3	1389	4.69
HOUSTON	385	4.48	2.25	51.3	1145	4.50
1969 MODEL VEHICLES						
KANSAS CITY	299	3.65	1.81	42.4	1562	5.34
HOUSTON	306	3.67	1.92	44.1	1337	5.33

68-69 STANDARDS: HC-275 ppm, CO-1.5% (HC-410 ppm, CO-2.3% FOR VOLKS)

TABLE 7
EMISSION LEVELS FOR 1970 MODEL VEHICLES
KANSAS CITY

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	20	10.3	50	50	40	2.44	0.78	2.34	1.33	31.2	21.6	24.7	2.06	4.32	1.18	4.12	1.42
CHRY CORP	60	10.1	33	28	18	2.74	1.09	2.60	1.36	40.9	23.2	34.7	1.81	5.74	1.54	5.52	1.34
PLYM	42	9.6	36	36	24	2.74	1.23	2.58	1.39	38.4	24.0	32.0	1.85	5.80	1.57	5.58	1.34
DODGE	13	10.6	31	15	8	2.54	0.49	2.49	1.23	40.8	17.4	37.0	1.62	5.65	1.57	5.42	1.38
CHRY	5	12.7	20	0	0	3.27	0.95	3.14	1.34	61.7	22.7	57.8	1.52	5.40	1.39	5.24	1.33
FORD MO CO.	124	12.8	23	48	15	2.72	0.72	2.64	1.28	26.4	13.8	22.7	1.79	4.95	1.74	4.62	1.47
FORD	115	13.0	22	49	17	2.73	0.72	2.65	1.27	26.3	14.0	22.6	1.80	5.02	1.77	4.68	1.48
MERC	6	9.4	0	50	0	2.96	0.56	2.91	1.21	25.8	14.8	21.9	1.91	3.96	1.12	3.81	1.34
LINC	3	10.2	100	0	0	1.69	0.33	1.66	1.24	29.3	2.6	29.2	1.09	4.27	0.54	4.25	1.13
GM	171	11.0	37	22	16	2.66	1.11	2.47	1.46	39.1	20.5	34.1	1.72	4.11	1.33	3.88	1.43
CHEV	90	9.8	32	17	12	2.80	1.05	2.61	1.45	41.7	18.3	37.7	1.60	3.97	1.15	3.79	1.40
PONT	27	11.5	59	48	37	2.58	1.76	2.24	1.65	28.6	27.3	22.5	1.91	3.76	1.43	3.52	1.44
OLDS	24	10.9	50	17	17	2.27	0.77	2.15	1.41	40.9	20.5	35.9	1.72	3.53	1.16	3.34	1.42
BUICK	25	13.9	16	20	8	2.68	0.60	2.62	1.27	40.4	17.5	36.7	1.57	5.19	1.19	5.04	1.29
CADI	5	14.8	40	20	20	2.25	0.46	2.21	1.23	33.1	16.1	28.6	1.97	5.79	1.37	5.63	1.32
VOLKS & MISC	20	8.5	65	95	65	2.28	1.21	2.07	1.55	17.3	4.3	16.7	1.31	4.01	0.87	3.92	1.24
TOTAL	395	11.2	34	36	20	2.66	0.99	2.51	1.40	33.9	19.3	28.5	1.83	4.63	1.59	4.34	1.45

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 8
EMISSION LEVELS FOR 1970 MODEL VEHICLES
HOUSTON

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	20	10.7	30	50	20	2.71	0.78	2.61	1.32	26.6	15.5	23.1	1.72	5.28	1.90	4.95	1.46
CHRY CORP	60	11.4	22	23	13	3.08	1.72	2.84	1.43	48.0	35.3	38.9	1.89	6.20	2.17	5.67	1.66
PLYM	30	12.6	20	30	13	2.78	0.80	2.68	1.31	39.7	34.1	32.3	1.84	6.56	2.22	5.91	1.78
DODGE	26	9.9	23	15	12	3.45	2.42	3.05	1.56	58.0	37.7	48.0	1.88	5.88	2.25	5.39	1.58
CHRY	4	11.5	25	25	25	2.91	0.91	2.81	1.36	45.1	25.5	40.0	1.78	5.78	0.63	5.76	1.11
FORD MO CO.	116	14.2	20	34	13	2.98	1.33	2.81	1.38	37.6	22.2	31.5	1.87	4.65	1.83	4.26	1.56
FORD	107	14.4	20	34	11	3.03	1.38	2.84	1.39	38.4	22.8	32.1	1.87	4.60	1.85	4.21	1.57
MERC	7	12.3	33	44	33	2.42	0.52	2.37	1.23	29.3	15.2	25.0	1.92	4.93	1.79	4.65	1.44
LINC	2	10.6	0	0	0	2.93	0.08	2.93	1.03	32.4	2.6	32.4	1.08	5.95	0.50	5.94	1.11
GM	169	12.9	25	18	12	3.02	1.61	2.73	1.56	43.6	22.9	37.5	1.80	4.20	1.56	3.93	1.45
CHEV	86	12.7	15	14	6	3.38	1.86	3.07	1.52	45.5	22.3	39.7	1.76	4.17	1.45	3.93	1.42
PONT	27	13.8	22	30	19	2.87	1.11	2.65	1.53	39.4	23.6	32.5	1.95	3.54	1.21	3.32	1.46
OLDS	22	13.3	64	41	36	2.41	1.77	1.98	1.84	32.4	19.3	27.6	1.79	3.60	1.09	3.44	1.36
BUICK	24	12.5	25	8	8	2.67	0.61	2.61	1.25	53.0	26.3	46.4	1.73	4.85	1.60	4.58	1.42
CADI	8	12.5	50	0	0	2.27	0.39	2.24	1.19	40.3	10.8	39.2	1.28	6.61	1.91	6.34	1.38
VOLKS & MISC	20	10.6	25	70	20	3.05	1.35	2.83	1.49	22.9	10.7	21.1	1.50	3.90	0.96	3.79	1.28
TOTAL	387	12.8	24	28	13	3.00	1.50	2.77	1.47	40.5	25.2	33.8	1.85	4.69	1.88	4.31	1.54

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 9
EMISSION LEVELS FOR 1970 MODEL VEHICLES
LOS ANGELES

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	NOX GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD
AMC	19	7.4	53	47	37	2.20	0.73	2.09	1.41	29.1	20.7	22.6	2.14	5.18	1.38	5.00	1.33
CHRY CORP	57	8.4	54	47	39	2.43	0.86	2.31	1.37	35.4	27.5	26.0	2.30	6.30	1.90	5.96	1.43
PLYM	27	7.8	70	67	63	2.16	0.68	2.06	1.34	30.0	27.9	21.5	2.20	6.11	1.88	5.76	1.47
DODGE	22	9.2	45	32	23	2.65	1.06	2.50	1.40	37.8	27.6	27.9	2.48	6.65	2.17	6.27	1.45
CHRY	8	8.5	25	25	0	2.75	0.48	2.72	1.20	47.3	24.4	40.8	1.85	5.96	1.23	5.85	1.24
FORD MO CO.	81	7.7	38	38	21	2.82	2.87	2.47	1.50	32.0	18.5	26.9	1.84	5.02	1.56	4.76	1.41
FORD	73	7.7	36	38	21	2.87	3.01	2.50	1.52	32.3	18.0	27.5	1.80	5.09	1.60	4.81	1.43
MERC	6	7.5	67	33	33	2.29	0.81	2.18	1.39	33.9	26.6	25.1	2.43	4.25	0.29	4.24	1.07
LINC	2	7.6	50	50	0	2.25	0.53	2.22	1.27	16.6	10.3	14.9	1.95	4.73	2.32	4.44	1.67
GM	175	8.4	54	36	27	2.36	1.25	2.12	1.54	33.5	20.0	28.1	1.86	4.72	1.65	4.39	1.50
CHEV	90	7.9	43	26	16	2.47	0.99	2.29	1.50	35.0	18.3	30.9	1.65	4.50	1.59	4.22	1.45
PONT	30	9.3	60	50	40	2.38	1.49	2.14	1.55	32.6	23.4	25.4	2.10	4.17	1.37	3.90	1.50
OLDS	23	8.5	87	74	65	2.11	2.25	1.83	1.86	22.1	19.7	16.7	2.12	4.56	1.78	4.10	1.73
BUICK	23	7.9	57	30	26	2.08	0.49	2.03	1.28	37.3	19.1	32.7	1.71	5.63	1.43	5.45	1.30
CADI	9	12.5	56	11	11	2.12	0.33	2.10	1.18	40.8	13.2	38.6	1.45	6.78	1.08	6.70	1.18
VOLKS & MISC	20	7.6	60	50	35	2.31	1.24	2.09	1.53	21.3	8.6	19.5	1.58	4.18	1.38	3.95	1.43
TOTAL	352	8.2	51	40	29	2.46	1.71	2.22	1.50	32.5	20.8	28.6	1.94	5.04	1.74	4.71	1.48

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 10
EMISSION LEVELS FOR 1970 MODEL VEHICLES
DETROIT

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	NOX GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD
AMC	20	9.2	50	50	45	2.55	0.75	2.45	1.33	26.1	17.7	21.6	1.87	4.86	1.62	4.60	1.42
CHRY CORP	60	9.7	17	28	13	3.05	0.93	2.92	1.35	45.5	30.4	35.1	2.19	5.47	1.64	5.19	1.42
PLYM	28	9.5	25	39	21	2.72	0.77	2.61	1.35	35.9	29.7	26.2	2.29	4.81	1.51	4.53	1.46
DODGE	21	9.0	14	24	10	3.05	0.68	2.98	1.25	48.3	27.4	40.5	1.91	6.41	1.63	6.17	1.34
CHRY	11	11.8	0	9	0	3.86	1.24	3.70	1.36	64.5	30.1	56.1	1.87	5.35	1.09	5.25	1.22
FORD MO CO.	81	9.5	14	27	10	3.44	2.10	3.16	1.44	33.2	16.3	29.5	1.64	4.33	1.48	4.09	1.42
FORD	66	9.5	14	30	11	3.43	2.24	3.13	1.45	30.7	14.4	27.6	1.59	4.39	1.58	4.11	1.46
MERC	13	9.1	15	15	8	3.55	1.48	3.30	1.46	43.0	21.6	37.8	1.73	4.02	0.88	3.92	1.27
LINC	2	13.7	0	0	0	3.09	0.06	3.09	1.02	49.8	1.5	49.8	1.03	4.44	1.04	4.38	1.27
GM	171	13.7	25	19	9	3.08	1.31	2.84	1.48	43.6	23.0	37.5	1.78	3.85	1.48	3.56	1.51
CHEV	90	15.7	19	20	7	3.36	1.45	3.08	1.51	44.2	23.1	37.8	1.83	3.70	1.48	3.38	1.57
PONT	28	10.7	29	36	21	2.88	1.35	2.63	1.53	31.7	16.3	27.9	1.70	3.75	1.25	3.55	1.40
OLDS	23	13.9	48	17	13	2.35	0.62	2.28	1.30	42.2	22.6	37.1	1.68	3.44	1.26	3.22	1.45
BUICK	23	10.4	17	4	0	3.19	0.93	3.07	1.33	57.5	25.1	52.1	1.61	4.41	1.49	4.20	1.37
CADI	7	10.7	43	0	0	2.26	0.33	2.24	1.16	42.8	15.7	40.6	1.42	5.78	1.29	5.64	1.28
VOLKS & MISC	20	7.9	60	70	55	2.27	0.81	2.16	1.37	23.8	12.6	21.2	1.63	3.43	1.21	3.23	1.45
TOTAL	352	11.5	24	27	14	3.09	1.46	2.86	1.45	39.4	23.3	32.9	1.86	4.27	1.62	3.95	1.51

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 11
EMISSION LEVELS FOR 1970 MODEL VEHICLES
DENVER

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	20	9.6	0	15	0	3.76	1.09	3.63	1.33	46.6	16.3	43.6	1.49	4.19	1.57	3.92	1.45
CHRY CORP	60	9.1	2	0	0	4.85	4.59	4.24	1.52	79.6	32.4	73.9	1.47	3.93	1.62	3.55	1.63
PLYM	32	9.1	3	0	0	3.81	1.42	3.63	1.34	71.4	30.0	66.2	1.48	3.99	1.55	3.66	1.57
DODGE	20	9.2	0	0	0	6.53	7.57	5.17	1.74	81.9	30.0	77.6	1.39	3.97	1.67	3.48	1.78
CHRY	8	8.9	0	0	0	4.79	0.62	4.76	1.14	106.9	35.3	101.8	1.40	3.58	1.39	3.32	1.54
FORD MO CO.	81	9.9	2	5	0	4.15	1.41	3.94	1.34	52.6	21.3	48.5	1.50	4.21	1.79	3.82	1.58
FORD	58	10.1	3	7	0	4.25	1.55	3.99	1.42	51.5	24.1	46.5	1.58	4.17	1.91	3.75	1.62
MERC	21	9.4	0	0	0	3.90	0.98	3.79	1.24	55.2	11.9	54.0	1.23	4.26	1.54	3.97	1.50
LINC	2	8.3	0	0	0	4.08	0.68	4.05	1.18	55.1	5.6	54.9	1.11	4.62	0.26	4.62	1.06
GM	171	10.8	8	2	1	4.24	1.73	3.93	1.48	71.0	29.4	65.8	1.54	3.53	1.28	3.30	1.47
CHEV	90	10.5	9	1	0	4.66	1.88	4.28	1.53	64.8	25.7	59.9	1.50	3.55	1.06	3.35	1.45
PONT	28	10.1	11	7	4	4.07	1.96	3.73	1.51	60.3	29.9	53.6	1.65	4.14	1.94	3.74	1.59
OLDS	22	12.9	9	0	0	3.39	0.77	3.30	1.24	75.8	16.3	73.9	1.27	2.97	1.08	2.90	1.41
BUICK	23	10.2	0	0	0	3.62	1.30	3.63	1.34	86.9	30.7	82.1	1.41	3.48	1.15	3.27	1.45
CADI	8	12.2	0	0	0	3.63	0.49	3.60	1.15	118.2	30.9	114.0	1.36	2.98	0.80	2.89	1.30
VOLKS & MISC	20	8.5	10	0	0	3.39	1.09	3.23	1.37	41.3	9.0	40.3	1.25	4.16	1.25	4.00	1.32
TOTAL	352	10.1	5	3	0	4.25	2.39	3.92	1.45	65.1	29.3	59.1	1.56	3.83	1.51	3.53	1.52

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 12
EMISSION LEVELS FOR 1970 MODEL VEHICLES
WASHINGTON

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	30	10.8	37	73	37	2.57	0.94	2.42	1.42	21.0	17.7	16.0	2.09	4.77	1.57	4.50	1.42
CHRY CORP	66	10.7	14	26	12	3.15	1.01	3.01	1.35	39.0	18.5	33.9	1.79	5.82	1.78	5.55	1.37
PLYM	28	10.6	18	25	14	2.96	0.89	2.84	1.31	37.0	18.0	32.1	1.79	6.00	2.00	5.69	1.40
DODGE	29	10.5	14	34	14	2.99	0.80	2.89	1.31	36.0	18.3	31.0	1.82	5.60	1.71	5.34	1.38
CHRY	9	11.9	0	0	0	4.23	1.36	4.04	1.37	55.4	15.0	53.5	1.33	5.96	1.27	5.83	1.26
FORD MO CO.	75	11.3	28	51	24	3.17	2.76	2.79	1.53	24.9	15.1	20.8	1.85	4.80	1.44	4.64	1.52
FORD	65	11.3	28	51	25	2.94	1.10	2.76	1.41	24.2	12.9	20.8	1.79	4.84	1.85	4.51	1.46
MERC	8	11.1	13	50	13	5.46	7.89	3.49	2.25	25.5	21.1	19.6	2.15	4.49	1.83	4.32	1.91
LINC	2	12.8	100	50	50	1.50	0.07	1.50	1.05	42.8	48.3	25.9	4.67	3.19	1.75	2.96	1.79
GM	151	11.1	34	33	17	2.95	1.73	2.63	1.58	31.5	16.7	27.4	1.74	4.53	1.54	4.29	1.40
CHEV	76	10.6	24	22	8	3.22	1.72	2.91	1.55	34.9	18.0	30.4	1.74	4.17	1.22	3.97	1.39
PONT	24	12.4	46	71	33	3.10	2.54	2.60	1.73	21.4	11.6	18.5	1.77	4.22	1.07	4.10	1.29
OLDS	20	11.5	60	40	35	2.25	1.08	2.01	1.62	28.1	15.3	24.7	1.67	4.30	0.89	3.91	1.24
BUICK	24	11.0	29	29	13	2.51	0.68	2.42	1.31	34.2	15.5	31.3	1.53	5.73	1.81	5.45	1.38
CADI	7	11.4	43	14	14	3.07	1.99	2.68	1.70	29.4	11.0	28.0	1.38	6.93	2.45	6.48	1.52
VOLKS & MISC	21	12.1	33	76	29	2.70	0.94	2.54	1.43	19.2	7.2	18.0	1.43	3.88	0.75	3.81	1.22
TOTAL	343	11.1	29	42	20	2.99	1.82	2.71	1.51	29.8	17.4	25.0	1.86	4.82	1.70	4.53	1.44

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

Table 13
SUMMARY OF EMISSIONS (ARITHMETIC MEANS)
FOR 1970 MODEL VEHICLES

	HYDROCARBONS gms/mi	CARBON MONOXIDE gms/mi	NO_{x_c} gms/mi
KANSAS CITY	2.66	33.9	4.63
HOUSTON	3.00	40.5	4.69
LOS ANGELES	2.46	32.5	5.04
DETROIT	3.08	39.4	4.27
WASHINGTON	2.99	29.8	4.82
DENVER	4.25	65.1	3.83
TOTAL EXCLUDING DENVER	2.83	35.3	4.69

70-71 STANDARDS: HC-2.2 gm/mi, CO-23 gm/mi

TABLE 14
EMISSION LEVELS FOR 1971 MODEL VEHICLES
HOUSTON-PHASE 1

MANUFACTURER / MAKE	N	MEAN MILES	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	9	12.7	78	22	22	1.89	0.63	1.81	1.38	34.5	15.1	30.2	1.87	3.38	1.22	3.15	1.52
CHRY CORP	10	19.0	80	10	10	1.95	0.59	1.88	1.34	38.2	11.1	36.5	1.39	4.19	1.80	3.78	1.65
PLYM	4	27.0	100	25	25	1.21	0.39	1.07	1.29	36.4	13.0	34.3	1.51	3.06	1.31	2.87	1.52
DODGE	6	13.7	67	0	0	2.12	0.68	2.03	1.38	39.4	10.8	38.1	1.34	4.93	1.76	4.55	1.64
CHRY	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FORD MO CO.	14	25.9	79	50	50	1.86	0.32	1.83	1.19	26.5	11.0	24.3	1.57	4.24	1.56	3.99	1.43
FORD	14	25.9	79	50	50	1.86	0.32	1.83	1.19	26.5	11.0	24.3	1.57	4.24	1.56	3.99	1.43
MERC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	23	7.3	100	74	74	1.14	0.39	1.08	1.42	19.8	11.8	17.3	1.67	2.60	0.50	2.56	1.21
CHEV	13	7.1	100	62	62	1.38	0.33	1.34	1.29	23.1	14.1	20.0	1.72	2.68	0.62	2.62	1.26
PONT	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OLDS	5	9.8	100	100	100	0.78	0.17	0.76	1.27	12.4	4.0	11.7	1.53	2.58	0.09	2.58	1.03
BUICK	4	4.8	100	75	75	0.94	0.21	0.93	1.26	18.9	7.8	17.9	1.43	2.52	0.43	2.49	1.17
CADI	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOLKS & MISC	9	11.8	89	56	44	1.55	0.32	1.52	1.21	27.0	14.5	23.9	1.67	2.95	0.82	2.84	1.34
TOTAL	65	14.5	88	49	48	1.58	0.55	1.48	1.45	27.1	13.8	23.6	1.73	3.35	1.35	3.12	1.46

*** APPLICABLE STANDARDS: HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 15
EMISSION LEVELS FOR 1971 MODEL VEHICLES
LOS ANGELES-PHASE 1

MANUFACTURER / MAKE	N	MEAN MILES	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	8	29.4	100	100	100	1.06	0.35	1.01	1.42	12.6	5.1	11.6	1.57	2.36	0.69	2.27	1.35
CHRY CORP	23	29.3	91	30	30	1.74	1.41	1.49	1.66	34.4	19.2	28.6	2.09	3.49	1.13	3.30	1.44
PLYM	12	27.3	92	17	17	1.56	0.43	1.44	1.34	42.6	19.9	38.5	1.61	3.40	1.23	3.16	1.54
DODGE	6	35.2	100	67	67	1.51	0.84	1.37	1.66	22.9	19.2	16.0	2.66	3.55	1.08	3.40	1.40
CHRY	5	27.2	80	20	20	2.61	2.96	1.79	2.45	28.6	5.8	28.0	1.24	3.65	1.16	3.53	1.32
FORD MO CO.	38	40.6	93	87	87	1.24	0.43	1.17	1.41	14.0	7.3	12.6	1.57	3.33	0.67	3.26	1.23
FORD	24	44.8	92	83	83	1.23	0.46	1.16	1.45	14.3	8.2	12.6	1.66	3.21	0.54	3.16	1.20
MERC	6	23.5	100	100	100	1.27	0.30	1.24	1.23	12.4	1.8	12.3	1.16	3.82	0.96	3.71	1.32
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	40	35.3	95	78	75	1.01	0.47	0.93	1.47	15.8	9.5	13.3	1.83	2.89	0.65	2.82	1.26
CHEV	22	36.0	91	68	64	1.14	0.55	1.06	1.45	18.0	8.5	16.0	1.66	3.03	0.75	2.94	1.29
PONT	6	35.8	100	67	67	1.15	0.26	1.13	1.26	21.8	14.6	17.1	2.30	2.96	0.43	2.94	1.16
OLDS	4	31.8	100	100	100	0.69	0.20	0.67	1.33	6.2	2.6	5.8	1.61	2.94	0.38	2.93	1.13
BUICK	6	34.7	100	100	100	0.77	0.17	0.76	1.26	10.4	2.1	10.2	1.23	2.43	0.50	2.39	1.25
CADI	2	35.0	100	100	100	0.51	0.11	0.50	1.25	10.2	3.0	10.0	1.34	2.36	0.07	2.36	1.01
VOLKS & MISC	11	36.2	73	55	36	1.67	0.56	1.59	1.41	24.1	8.5	22.8	1.41	2.69	0.85	2.58	1.33
TOTAL	112	35.1	92	70	67	1.29	0.80	1.16	1.55	19.7	13.9	16.0	1.91	3.07	0.86	2.96	1.33

*** APPLICABLE STANDARDS: HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 16
EMISSION LEVELS FOR 1971 MODEL VEHICLES
DETROIT-PHASE 1

MANUFACTURER / MAKE	N	MEAN MILES	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHRY CORP	9	13.2	78	11	11	1.92	0.42	1.87	1.24	43.2	14.7	40.8	1.46	3.37	0.95	3.26	1.31
PLYM	4	7.0	75	0	0	2.17	0.15	2.16	1.07	50.8	9.0	50.1	1.21	2.93	0.67	2.87	1.27
DODGE	3	12.7	67	0	0	2.00	0.40	1.97	1.21	45.4	16.2	43.5	1.41	4.01	1.33	3.86	1.39
CHRY	2	26.5	100	50	50	1.30	0.21	1.30	1.17	25.0	7.5	24.5	1.35	3.28	0.63	3.25	1.21
FORD MO CO.	15	19.1	33	47	33	2.36	0.46	2.32	1.22	31.0	10.8	28.5	1.84	3.86	1.53	3.57	1.52
FORD	15	19.1	33	47	33	2.36	0.46	2.32	1.22	31.0	10.8	28.5	1.84	3.86	1.53	3.57	1.52
MERC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	24	18.8	96	75	75	1.34	0.54	1.25	1.45	21.4	13.2	18.7	1.67	2.49	0.65	2.41	1.31
CHEV	13	17.2	92	85	85	1.46	0.61	1.38	1.44	20.6	9.2	19.0	1.51	2.67	0.70	2.58	1.31
PONT	2	12.5	100	0	0	1.80	0.74	1.52	1.62	45.5	31.2	39.8	2.12	1.71	0.59	1.65	1.42
OLDS	3	25.0	100	100	100	0.81	0.32	0.77	1.44	13.0	4.3	12.5	1.43	2.92	0.08	2.92	1.03
BUICK	6	21.0	100	67	67	1.26	0.22	1.25	1.18	19.3	10.7	17.1	1.68	2.15	0.34	2.13	1.17
CADI	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOLKS & MISC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	48	17.6	73	54	50	1.77	0.67	1.64	1.51	28.5	16.5	24.1	1.81	3.38	1.20	2.98	1.44

*** APPLICABLE STANDARDS: HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 17
EMISSION LEVELS FOR 1971 MODEL VEHICLES
DENVER-PHASE 1

MANUFACTURER / MAKE	N	MEAN MILES	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	20	19.1	90	10	10	3.12	1.27	2.87	1.52	74.1	39.6	63.3	1.88	2.45	1.03	2.18	1.41
CHRY CORP	18	17.6	6	0	0	3.24	1.00	3.09	1.33	81.4	27.3	76.9	1.42	2.97	1.31	2.66	1.66
PLYM	14	19.6	7	0	0	2.59	0.72	2.51	1.26	77.0	27.9	72.4	1.44	2.98	1.51	2.61	1.75
DODGE	3	9.7	0	0	0	4.33	1.64	4.06	1.51	90.2	19.9	88.8	1.25	3.24	0.74	3.17	1.28
CHRY	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FORD MO CO.	26	26.2	4	0	0	3.07	1.16	2.96	1.29	51.2	12.4	49.8	1.27	4.45	1.67	4.15	1.46
FORD	24	26.4	4	0	0	3.12	1.19	3.00	1.29	51.8	12.7	50.3	1.28	4.45	1.74	4.13	1.49
MERC	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	57	19.5	61	0	0	2.16	0.76	2.03	1.44	68.6	25.9	64.1	1.45	2.29	0.79	2.11	1.46
CHEV	34	18.7	50	0	0	2.37	0.55	2.31	1.25	76.5	25.4	72.6	1.39	2.14	0.42	1.99	1.48
PONT	5	26.4	100	0	0	1.82	0.17	1.82	1.10	45.9	15.3	44.2	1.35	2.56	0.46	2.51	1.18
OLDS	6	14.3	67	0	0	2.13	0.91	2.00	1.47	66.4	16.9	64.5	1.32	2.72	0.68	2.65	1.29
BUICK	9	22.0	78	0	0	2.08	0.99	1.92	1.50	60.5	29.5	54.9	1.58	2.16	0.88	1.98	1.58
CADI	3	19.3	100	0	0	0.67	0.18	0.65	1.31	46.9	11.6	46.0	1.28	2.34	0.76	2.26	1.40
VOLKS & MISC	23	23.3	35	4	0	2.43	0.64	2.35	1.30	44.3	13.1	42.3	1.39	2.48	0.77	2.39	1.34
TOTAL	144	21.0	36	2	1	2.63	1.03	2.46	1.46	64.0	27.6	58.5	1.54	2.86	1.42	2.51	1.61

*** APPLICABLE STANDARDS: HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 18
EMISSION LEVELS FOR 1971 MODEL VEHICLES
HOUSTON-PHASE 2

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	9	5.7	33	33	11	2.27	0.53	2.22	1.27	29.0	11.7	26.4	1.65	5.05	1.66	4.80	1.41
CHRY CORP	10	5.3	10	20	0	2.97	0.73	2.88	1.32	51.1	25.0	45.9	1.63	5.43	2.11	5.09	1.46
PLYM	4	5.3	0	0	0	3.09	0.53	3.05	1.20	73.8	22.7	71.3	1.35	4.20	1.14	4.10	1.29
DODGE	6	5.3	17	33	0	2.89	0.88	2.77	1.39	36.0	11.3	34.3	1.42	6.24	2.28	5.96	1.49
CHRY	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FORD MO CO.	14	5.0	14	14	7	3.20	1.15	3.04	1.38	40.1	22.7	35.2	1.71	4.85	2.24	4.21	1.85
FORD	14	5.0	14	14	7	3.20	1.15	3.04	1.38	40.1	22.7	35.2	1.71	4.85	2.24	4.21	1.85
MERC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	23	5.2	61	61	43	1.87	0.89	1.67	1.64	24.9	16.9	20.8	1.83	3.55	1.11	3.39	1.37
CHEV	13	5.1	46	46	23	2.22	0.85	2.05	1.56	28.8	17.5	24.8	1.77	3.81	1.08	3.63	1.41
PONT	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OLDS	5	5.3	80	100	80	1.32	0.51	1.25	1.39	12.3	4.6	11.6	1.48	3.68	1.51	3.49	1.42
BUICK	4	6.0	75	50	50	1.65	1.06	1.43	1.81	30.8	20.5	26.7	1.80	2.68	0.18	2.67	1.07
CADI	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOLKS & MISC	9	5.5	67	44	33	2.10	0.48	2.05	1.27	31.6	19.1	26.6	1.87	3.09	1.14	2.87	1.53
TOTAL	65	5.3	40	38	23	2.41	1.00	2.21	1.55	33.7	21.0	28.1	1.86	4.27	1.83	3.88	1.58

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 19
EMISSION LEVELS FOR 1971 MODEL VEHICLES
LOS ANGELES-PHASE 2

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC	8	5.4	100	38	38	1.64	0.39	1.60	1.27	27.2	14.1	22.9	2.09	2.94	1.03	2.77	1.46
CHRY CORP	23	5.4	78	43	43	1.75	0.73	1.63	1.48	39.1	27.5	30.3	2.13	3.78	1.57	3.49	1.52
PLYM	12	5.4	75	33	33	1.82	0.77	1.70	1.43	41.3	29.0	31.9	2.19	3.77	1.59	3.43	1.49
DODGE	6	5.4	100	67	67	1.31	0.44	1.24	1.45	24.5	15.9	20.4	1.97	4.28	2.14	3.90	1.59
CHRY	5	4.8	60	40	40	2.13	0.77	2.01	1.47	51.4	31.9	43.0	1.99	3.19	0.25	3.14	1.08
FORD MO CO.	30	5.6	87	60	57	1.47	0.60	1.36	1.51	22.4	13.4	19.1	1.77	3.56	1.15	3.42	1.35
FORD	24	5.6	83	54	50	1.57	0.63	1.43	1.57	24.1	14.4	20.3	1.83	3.59	1.10	3.45	1.32
MERC	6	5.7	100	83	83	1.10	0.16	1.08	1.18	15.9	5.2	15.1	1.45	3.56	1.46	3.32	1.51
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	40	5.2	85	83	75	1.74	1.74	1.38	1.84	17.1	14.5	13.1	2.04	3.44	0.99	3.31	1.33
CHEV	22	5.2	82	82	73	2.07	2.21	1.61	1.87	17.6	13.6	14.0	1.95	3.62	0.98	3.49	1.32
PONT	6	5.5	83	67	67	1.67	0.55	1.59	1.43	23.1	20.0	14.1	3.04	2.98	0.71	2.90	1.28
OLDS	4	5.4	100	100	100	0.98	0.77	0.79	2.06	6.0	2.1	5.7	1.43	4.33	1.21	4.22	1.29
BUICK	6	5.2	83	83	67	1.45	1.02	1.24	1.77	17.6	6.7	16.6	1.46	2.69	0.67	2.61	1.31
CADI	2	4.8	100	100	100	0.72	0.19	0.71	1.31	13.6	4.6	13.2	1.41	3.34	0.37	3.33	1.12
VOLKS & MISC	11	5.1	64	9	9	1.93	0.76	1.82	1.44	32.2	9.6	30.5	1.46	2.37	0.94	2.21	1.42
TOTAL	112	5.4	83	58	54	1.68	1.16	1.48	1.63	25.2	19.1	19.5	2.09	3.41	1.22	3.21	1.42

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 20
EMISSION LEVELS FOR 1971 MODEL VEHICLES
DETROIT-PHASE 2

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	% BELOW STANDARDS CO	% BELOW STANDARDS BOTH**	HYDROCARBONS GM/MI ARITHMETIC MEAN	HYDROCARBONS GM/MI ARITHMETIC SD	HYDROCARBONS GM/MI GEOMETRIC MEAN	HYDROCARBONS GM/MI GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	CARBON MONOXIDE GM/MI ARITHMETIC SD	CARBON MONOXIDE GM/MI GEOMETRIC MEAN	CARBON MONOXIDE GM/MI GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	NOX GM/MI ARITHMETIC SD	NOX GM/MI GEOMETRIC MEAN	NOX GM/MI GEOMETRIC SD
AMC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHRY CORP	9	6.0	33	22	22	2.51	0.76	2.39	1.40	40.9	20.2	35.2	1.90	4.17	1.15	4.05	1.29
PLYM	4	6.3	25	25	25	2.72	0.69	2.65	1.31	41.6	24.0	33.8	2.33	4.08	0.97	4.00	1.25
DODGE	3	6.2	67	33	33	2.68	1.08	1.92	1.61	28.7	13.5	26.8	1.56	4.88	1.50	4.73	1.35
CHRY	2	4.9	0	0	0	2.72	0.24	2.71	1.09	58.1	10.8	57.6	1.21	3.29	0.35	3.28	1.11
FORD MU CO.	15	5.2	7	47	7	3.13	0.78	3.03	1.29	30.1	14.2	27.0	1.64	4.91	1.73	4.63	1.42
FORD	15	5.2	7	47	7	3.13	0.78	3.03	1.29	30.1	14.2	27.0	1.64	4.91	1.73	4.63	1.42
MERC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	24	5.6	42	46	29	2.64	1.57	2.28	1.72	28.7	21.9	22.5	2.06	2.98	0.91	2.86	1.36
CHEV	13	5.1	38	46	31	2.89	1.72	2.52	1.71	29.8	23.1	24.9	1.84	3.00	0.91	2.89	1.32
PONT	2	6.3	50	50	50	2.03	1.00	1.90	1.68	52.3	55.4	34.6	3.94	1.99	0.84	1.90	1.54
OLDS	3	6.6	33	67	33	3.05	2.43	2.42	2.34	19.7	16.1	15.5	2.37	3.45	1.35	3.69	1.43
BUICK	6	5.4	50	33	17	2.08	0.98	1.89	1.62	23.1	13.4	18.8	2.18	2.43	0.29	2.42	1.10
CADI	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOLKS & MISC	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	48	5.6	29	42	21	2.77	1.25	2.51	1.56	31.5	19.6	25.9	1.92	3.40	1.51	3.55	1.45

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 21
EMISSION LEVELS FOR 1971 MODEL VEHICLES
DENVER-PHASE 2

MANUFACTURER / MAKE	N	MEAN MILES (K)	% BELOW STANDARDS HC	% BELOW STANDARDS CO	% BELOW STANDARDS BOTH**	HYDROCARBONS GM/MI ARITHMETIC MEAN	HYDROCARBONS GM/MI ARITHMETIC SD	HYDROCARBONS GM/MI GEOMETRIC MEAN	HYDROCARBONS GM/MI GEOMETRIC SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	CARBON MONOXIDE GM/MI ARITHMETIC SD	CARBON MONOXIDE GM/MI GEOMETRIC MEAN	CARBON MONOXIDE GM/MI GEOMETRIC SD	NOX GM/MI ARITHMETIC MEAN	NOX GM/MI ARITHMETIC SD	NOX GM/MI GEOMETRIC MEAN	NOX GM/MI GEOMETRIC SD
AMC	20	5.5	20	15	15	3.20	1.05	3.02	1.44	54.6	39.1	41.9	2.29	3.07	1.57	2.93	2.06
CHRY CORP	18	5.0	6	0	0	3.36	0.71	3.29	1.24	65.7	23.2	62.8	1.37	3.40	1.42	3.17	1.45
PLYM	14	4.8	7	0	0	3.24	0.66	3.18	1.24	60.6	18.9	58.1	1.36	3.52	1.54	3.19	1.60
DODGE	3	5.1	0	0	0	4.12	0.50	4.10	1.13	79.9	15.9	78.8	1.23	3.41	0.70	3.37	1.22
CHRY	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FORD MU CO.	26	5.1	4	12	4	3.24	0.78	3.16	1.26	38.0	12.1	36.1	1.40	4.68	1.56	4.41	1.44
FORD	24	5.1	4	13	4	3.25	0.81	3.17	1.25	38.6	12.5	36.5	1.41	4.63	1.61	4.35	1.46
MERC	1	3.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LINC	1	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GM	57	5.1	42	5	2	3.36	6.31	2.44	1.80	43.3	17.1	39.7	1.57	2.65	0.86	2.51	1.41
CHEV	34	5.2	26	3	0	4.27	8.06	2.95	1.84	47.8	18.0	43.8	1.60	2.57	0.77	2.45	1.38
PONT	5	4.5	60	20	20	2.27	0.63	2.21	1.30	29.1	16.7	25.9	1.69	2.79	0.23	2.78	1.09
OLDS	6	4.4	50	0	0	1.89	0.66	1.78	1.46	32.3	7.9	31.5	1.28	4.05	0.67	4.00	1.19
BUICK	9	5.6	67	11	0	2.24	0.89	2.11	1.42	42.0	14.5	39.8	1.43	2.03	0.66	1.93	1.40
CADI	3	4.4	100	0	0	1.05	0.46	0.99	1.52	42.5	6.5	42.2	1.16	2.43	0.20	2.42	1.09
VOLKS & MISC	23	5.4	48	26	17	2.40	0.65	2.32	1.30	33.7	13.7	30.1	1.73	2.78	0.97	2.63	1.41
TOTAL	144	5.2	28	10	6	3.16	4.01	2.71	1.56	45.2	22.8	39.6	1.71	3.19	1.41	2.88	1.61

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

Table 22
SUMMARY OF EMISSIONS (ARITHMETIC MEANS) FOR 1971 MODEL VEHICLES

	HYDROCARBONS gms/mi	CARBON MONOXIDE gms/mi	NO_{x_c} gms/mi
LOW MILEAGE ENGINES - PHASE I			
HOUSTON	1.58	27.1	3.35
LOS ANGELES	1.29	19.7	3.07
DETROIT	1.77	28.5	3.08
DENVER	2.63	64.0	2.86
STABILIZED ENGINES – PHASE 2			
HOUSTON	2.41	33.7	4.27
LOS ANGELES	1.68	25.2	3.41
DETROIT	2.77	31.5	3.80
DENVER	3.16	45.2	3.19

Table 23
SUMMARY OF SEVEN-MODE EMISSIONS TESTS 1968-1971 MODEL VEHICLES

MANUFACTURER	N	MEAN MILES (K)	% BELOW STANDARDS			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{x_c} gm/mi			
			HC	CO	BOTH	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
68 TOTAL	967	34.3	46	35	23	4.13	3.16	3.66	1.56	49.0	29.2	41.1	1.82	4.60	1.94	4.11	1.70
69 TOTAL	982	23.2	53	42	30	3.66	1.99	3.38	1.46	43.3	23.0	37.9	1.69	5.33	1.83	4.95	1.53
70 EXCLUDING DENVER	1829	11.0	32	35	19	2.83	1.53	2.60	1.48	35.3	21.9	29.2	1.89	4.69	1.73	4.36	1.49
70 DENVER	352	10.1	5	3	3	4.25	2.39	3.92	1.45	65.1	29.3	59.1	1.56	3.83	1.51	3.53	1.52
71 PHASE 1 EXCLUSING DENVER	225	0.25	87	60	58	1.47	0.74	1.34	1.55	23.7	15.0	19.5	1.89	3.16	1.10	2.99	1.39
71 PHASE 1 DENVER	144	0.21	36	2	1	2.63	1.03	2.46	1.46	64.0	27.6	58.5	1.54	2.86	1.42	2.54	1.63
71 PHASE 2 EXCLUDING DENVER	225	5.4	59	49	38	2.12	1.22	1.86	1.68	29.0	20.0	23.0	2.02	3.74	1.52	3.46	1.49
71 PHASE 2 DENVER	144	5.2	29	10	6	3.16	4.01	2.71	1.56	45.2	22.8	39.8	1.71	3.19	1.41	2.88	1.61

TABLE 24
TABULATION OF EMISSION LEVELS OF 1968 MODEL VEHICLES
BY ENGINE CID

MANUFACTURER / CID	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC																	
232	41	29.5	20	32	12	347.	134.	330.	1.36	2.12	1.13	1.83	1.79	1384.	563.	1255.	1.64
CHRY CORP																	
225	36	35.8	50	39	25	334.	227.	294.	1.58	1.96	1.20	1.71	1.66	1677.	623.	1495.	1.81
318	36	41.7	36	33	19	389.	397.	328.	1.60	1.82	0.85	1.64	1.64	1457.	457.	1359.	1.54
383	40	38.6	38	23	13	361.	313.	316.	1.56	2.24	1.01	2.03	1.60	1524.	493.	1443.	1.61
440	38	36.8	29	3	0	346.	152.	322.	1.44	2.97	1.61	2.68	1.55	961.	486.	804.	2.03
FORD MO CO.																	
200	50	32.5	62	76	56	293.	153.	276.	1.34	1.64	1.53	1.28	1.89	1912.	721.	1654.	1.97
302	37	37.6	24	73	19	355.	119.	339.	1.35	1.27	0.52	1.17	1.57	1647.	478.	1563.	1.42
390	36	38.4	53	53	39	276.	92.	262.	1.35	1.53	0.78	1.32	1.82	1489.	487.	1402.	1.44
429	38	32.9	45	11	5	323.	188.	299.	1.42	2.04	1.00	2.44	1.53	1083.	339.	930.	1.55
GM																	
230	43	33.8	40	28	26	297.	81.	286.	1.32	1.92	0.82	1.73	1.63	1279.	392.	1216.	1.39
250	43	29.8	84	63	58	240.	139.	219.	1.49	1.45	0.70	1.29	1.64	1323.	407.	1262.	1.37
307	48	32.3	4	38	2	485.	187.	456.	1.42	1.74	0.58	1.65	1.39	1572.	375.	1523.	1.30
327	80	32.5	13	8	1	440.	213.	404.	1.48	3.26	1.57	2.92	1.60	908.	462.	768.	1.92
350	143	32.7	55	19	14	284.	100.	272.	1.34	2.23	0.88	2.05	1.52	1166.	409.	1098.	1.43
396	37	33.6	38	22	16	534.	810.	364.	1.99	2.47	1.34	2.17	1.70	931.	465.	821.	1.69
430	37	35.4	61	5	0	263.	92.	250.	1.21	2.10	0.56	2.23	1.29	1206.	374.	1160.	1.32
455	31	36.1	68	29	29	277.	151.	252.	1.52	2.32	1.40	1.93	1.91	996.	364.	911.	1.60
472	31	40.4	87	58	55	211.	111.	194.	1.46	1.56	0.66	1.45	1.50	1373.	430.	1300.	1.42
VOLKS																	
91	40	30.2	28	40	18	469.	578.	342.	1.81	2.74	1.44	2.47	1.55	1298.	436.	1188.	1.64
97	49	42.2	71	82	65	422.	373.	350.	1.71	1.68	1.25	1.33	1.97	1065.	483.	942.	1.73

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

TABLE 25
TABULATION OF EMISSION LEVELS OF 1969 MODEL VEHICLES
BY ENGINE CID

MANUFACTURER / CID	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	CARBON MONOXIDE % ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	NOX PPM ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
AMC																	
232	22	19.9	25	50	9	350.	135.	332.	1.37	1.42	0.58	1.29	1.63	1805.	422.	1755.	1.28
CHRY CORP																	
225	39	19.7	59	41	31	296.	106.	283.	1.32	1.97	0.97	1.76	1.63	1849.	505.	1759.	1.43
318	44	23.9	41	32	23	304.	77.	295.	1.28	2.00	0.89	1.79	1.65	1536.	508.	1436.	1.49
383	37	28.9	46	46	32	306.	121.	286.	1.44	1.87	1.20	1.58	1.77	1457.	484.	1363.	1.49
440	35	20.2	51	26	23	349.	294.	300.	1.60	2.34	1.19	2.04	1.76	1154.	494.	1048.	1.58
FORD MO CO.																	
200	26	27.2	62	73	58	293.	112.	275.	1.42	1.31	0.49	1.23	1.44	1867.	523.	1783.	1.39
302	42	23.7	7	64	5	465.	421.	393.	1.66	1.45	0.58	1.35	1.50	1880.	434.	1826.	1.29
351	74	21.8	31	59	28	328.	112.	312.	1.36	1.48	0.68	1.34	1.57	1572.	476.	1480.	1.46
390	44	26.4	50	52	41	295.	130.	279.	1.35	1.60	0.80	1.41	1.69	1503.	510.	1404.	1.49
429	32	21.4	50	25	19	287.	111.	270.	1.40	2.27	1.13	1.98	1.76	1006.	353.	928.	1.57
GM																	
230	31	27.3	58	39	35	324.	266.	276.	1.64	1.88	1.02	1.66	1.65	1075.	365.	1009.	1.46
250	35	25.2	89	63	57	208.	73.	197.	1.39	1.45	0.54	1.35	1.50	1129.	386.	1061.	1.44
307	33	21.5	42	21	18	309.	79.	300.	1.28	2.06	0.77	1.95	1.40	1420.	325.	1378.	1.30
350	163	22.8	50	21	17	282.	75.	272.	1.33	2.17	0.87	2.00	1.51	1444.	440.	1363.	1.46
366	28	19.5	39	14	11	331.	183.	304.	1.45	2.19	0.71	2.08	1.41	1091.	349.	1032.	1.42
428	65	27.8	28	17	8	331.	102.	317.	1.34	2.37	0.96	2.21	1.45	1285.	405.	1185.	1.41
430	35	22.6	77	26	26	243.	53.	238.	1.22	1.92	0.65	1.80	1.47	1450.	402.	1386.	1.38
455	36	25.7	86	50	50	216.	67.	209.	1.29	1.97	1.59	1.63	1.74	1350.	484.	1177.	1.98
472	40	18.1	100	80	80	159.	30.	157.	1.19	1.26	0.38	1.20	1.36	1441.	373.	1388.	1.33
VOLKS																	
91	40	23.7	58	78	53	469.	316.	409.	1.64	2.01	0.99	1.88	1.39	1457.	385.	1353.	1.69

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

TABLE 26
TABULATION OF EMISSION LEVELS OF 1970 MODEL VEHICLES
BY ENGINE CID**EXCLUDING DENVER

MANUFACTURER / CID	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	NOX GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD
AMC																	
232	59	10.0	42	51	36	2.42	0.82	2.30	1.37	28.1	18.5	22.3	2.05	5.10	1.40	4.89	1.36
CHRY CORP																	
225	80	8.9	26	16	11	2.88	0.86	2.76	1.34	44.4	22.6	39.0	1.70	7.19	1.85	6.92	1.34
318	104	10.1	45	60	39	2.39	0.65	2.32	1.29	24.5	14.7	20.7	1.84	5.63	1.39	5.45	1.30
383	72	10.6	10	14	4	3.53	1.77	3.28	1.43	56.0	28.9	48.2	1.81	5.49	1.67	5.20	1.43
FORD MO CO.																	
200	120	14.9	25	49	21	2.73	0.79	2.64	1.29	27.7	18.4	22.5	1.94	5.07	1.93	4.62	1.59
302	81	9.3	32	44	17	3.24	3.78	2.68	1.61	27.3	13.8	24.0	1.69	3.36	1.07	3.17	1.39
351	108	9.9	8	29	5	3.34	2.05	3.09	1.40	36.4	20.3	31.2	1.78	5.25	1.36	5.07	1.31
390	51	10.2	29	31	20	2.85	1.09	2.67	1.44	36.7	20.5	31.2	1.80	5.31	1.37	5.13	1.33
429	37	10.4	30	22	16	2.73	0.91	2.60	1.36	30.0	16.6	32.1	1.65	4.29	1.38	4.10	1.36
GM																	
230	31	13.8	71	26	19	2.11	0.70	2.01	1.37	31.2	14.2	28.0	1.64	3.34	0.89	3.24	1.29
250	67	12.2	55	25	19	2.35	2.04	2.07	1.85	28.6	11.0	26.2	1.58	3.61	1.48	3.36	1.46
307	102	11.2	16	25	10	3.46	1.86	3.16	1.49	36.2	17.5	31.5	1.77	5.81	1.16	5.62	1.19
350	371	10.6	27	21	12	2.91	1.19	2.71	1.45	43.8	22.8	37.8	1.77	4.29	1.39	4.05	1.43
400	92	11.0	28	34	17	2.98	1.69	2.71	1.48	37.4	23.7	30.6	1.95	4.12	1.18	3.91	1.42
455	116	12.6	58	40	34	2.20	0.98	2.02	1.52	31.8	21.5	26.1	1.90	5.02	1.74	4.68	1.48
472	35	11.4	69	9	9	2.38	0.96	2.27	1.32	37.2	13.2	34.7	1.49	6.45	1.69	6.21	1.34
VOLKS & MISC																	
97	100	9.4	48	73	41	2.53	1.15	2.33	1.49	20.8	9.3	19.1	1.50	3.91	1.04	3.76	1.32

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

TABLE 27
TABULATION OF EMISSION LEVELS OF 1970 MODEL VEHICLES
BY ENGINE CID**DENVER ONLY

MANUFACTURER / CID	N	MEAN MILES (K)	% BELOW STANDARDS HC	CO	BOTH	HYDROCARBONS GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	CARBON MONOXIDE GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	NOX, GM/MI ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD
AML																	
232	11	10.3	0	27	0	3.42	0.80	3.34	1.25	44.5	18.9	40.4	1.62	4.36	1.76	4.03	1.52
CHRY CORP																	
225	13	8.0	0	0	0	4.67	1.92	4.41	1.39	81.5	29.5	79.3	1.28	5.37	1.60	5.09	1.44
318	20	9.2	5	0	0	3.62	1.07	3.47	1.34	66.1	31.9	60.8	1.49	3.58	1.37	3.32	1.53
383	15	9.1	0	0	0	4.79	0.85	4.22	1.21	77.7	20.2	72.6	1.48	4.17	1.39	3.98	1.49
FORD MO CO.																	
302	15	9.5	0	0	0	4.03	1.23	3.88	1.33	46.8	12.8	45.4	1.29	3.68	1.39	3.44	1.46
351	20	9.8	0	5	0	4.18	1.49	3.98	1.36	56.3	23.7	51.8	1.54	4.10	1.27	3.84	1.52
429	11	11.7	9	0	0	3.83	1.50	3.58	1.46	59.0	19.7	55.9	1.43	3.82	1.61	3.49	1.58
GM																	
250	20	9.6	45	0	0	3.19	2.01	2.77	1.67	44.4	15.1	42.0	1.40	3.29	1.05	3.15	1.35
307	17	9.3	0	0	0	5.36	1.99	5.08	1.39	60.4	13.3	59.0	1.24	3.60	0.76	3.53	1.24
350	70	10.8	1	1	1	4.77	1.33	4.59	1.32	79.1	26.2	74.4	1.45	3.46	1.25	3.22	1.48
400	21	10.0	5	5	0	3.95	2.00	3.64	1.47	62.3	28.5	56.5	1.58	4.02	2.06	3.59	1.61
455	25	10.5	8	0	0	3.16	0.89	3.05	1.30	72.4	20.3	69.4	1.37	3.82	0.96	3.71	1.29
VOLKS & MISC																	
97	20	8.5	10	0	0	3.39	1.09	3.23	1.37	41.3	9.0	40.3	1.25	4.16	1.25	4.00	1.32

*** APPLICABLE STANDARDS:HC-2.2 GM/MI CO-23. GM/MI ***

Table 28

MANUFACTURER/MAKE CID GROUPINGS

MANUFACTURER MAKE	1968-1969	1970	1971
AMC	232	199 232 304 360 390	232 258 304 360
CHRYSLER CORP.	225 318 383 440	198 225 318 340 383 449	198 225 318 340 360 449
FORD MOTOR CORP	220 302 351 390 429	170 200 240 250 302 351 360 390 428 429 460	98 122 170 200 240 250 302 351 360 390 400 460
CHEVROLET	230 250 307 327 350 396	230 250 292 307 350 400 402 454	140 250 292 307 350 400 402 454
PONTIAC	350 400 428	250 350 400 455	350 400 455
OLDSMOBILE	250 350 455	250 350 455	350 455
BUICK	350 430	250 350 455	350 455
CADILLAC	472	472 500	472 500
VOLKSWAGEN	91 97	97 103	97 103

TABLE 29
MILEAGE EFFECTS FOR 1968 AND 1969 MODEL VEHICLES

	YEAR	N	SIGNIFICANCE LEVEL %	INTERCEPT GM/MI MEAN	INTERCEPT GM/MI STANDARD ERROR	SLOPE GM/MI/1000MI MEAN	SLOPE GM/MI/1000MI STANDARD ERROR	% CHANGE 1000 MI
HC GM/MI	TOTAL 68	313	95	3.03	0.558	0.031	0.015	0.98
	TOTAL 69	318	95	2.94	0.229	0.030	0.013	0.98
CO GM/MI	TOTAL 68	313	*	43.6	5.81	0.241	0.180	-
	TOTAL 69	318	95	37.7	2.36	0.215	0.094	0.56
NOX GM/MI	TOTAL 68	313	*	5.11	0.338	-0.016	0.010	-
	TOTAL 69	318	*	5.60	0.247	-0.013	0.010	-

* SLOPE NOT SIGNIFICANTLY DIFFERENT FROM ZERO AT AT LEAST 95% LEVEL
1968 MEAN MILEAGE = 34.6 K
1969 MEAN MILEAGE = 24.0 K

TABLE 30
MILEAGE EFFECTS BY CITY 1971 MODEL VEHICLES

	CITY	N	SIGNIFICANCE LEVEL %	INTERCEPT GM/MI MEAN	INTERCEPT GM/MI STANDARD ERROR	SLOPE GM/MI/1000MI MEAN	SLOPE GM/MI/1000MI STANDARD ERROR	% CHANGE 1000 MI
HC GM/MI	HOUSTON	65	99	1.58	0.069	0.158	0.020	7.14
	LOS ANGELES	112	99	1.29	0.076	0.079	0.019	4.90
	DETROIT	48	99	1.76	0.096	0.191	0.033	7.54
	DENVER	144	*	2.63	0.086	0.106	0.075	-
	TOTAL	225	99	1.47	0.049	0.125	0.014	6.35
	EXCLUDE DENVER							
CO GM/MI	HOUSTON	65	99	27.1	1.71	1.25	0.452	3.98
	LOS ANGELES	112	99	19.7	1.31	1.13	0.347	4.66
	DETROIT	48	*	28.5	2.40	0.63	0.572	-
	DENVER	144	99	64.0	2.31	-3.75	0.392	-7.65
	TOTAL	225	99	23.7	1.00	1.06	0.248	3.78
	EXCLUDE DENVER							
NOX GM/MI	HOUSTON	64	99	3.37	0.169	0.182	0.030	4.45
	LOS ANGELES	112	99	3.07	0.169	0.182	0.030	4.45
	DETROIT	48	99	3.08	0.173	0.134	0.024	3.71
	DENVER	144	99	2.86	0.119	0.068	0.016	2.18
	TOTAL	224	99	3.16	0.073	0.113	0.014	3.13
	EXCLUDE DENVER							

* SLOPE NOT SIGNIFICANTLY DIFFERENT FROM ZERO AT AT LEAST 95% LEVEL

TABLE 31
MILEAGE EFFECTS FOR 1971 MODEL VEHICLES
EXCLUDING DENVER

	MAKE	N	SIGNIFICANCE LEVEL %	INTERCEPT GM/MI MEAN	INTERCEPT GM/MI STANDARD ERROR	SLOPE GM/MI/1000MI MEAN	SLOPE GM/MI/1000MI STANDARD ERROR	% CHANGE 1000 MI
HC GM/MI	AMC	17	99	1.50	0.161	0.091	0.029	4.49
	PLYM	20	99	1.67	0.101	0.115	0.037	5.38
	FORD	53	99	1.71	0.088	0.134	0.024	6.12
	CHEV	48	99	1.29	0.075	0.196	0.039	9.46
	BUICK	16	95	1.00	0.073	0.154	0.055	9.56
	CADI	3	99	0.56	0.071	0.046	0.004	6.18
	VOLKS	20	95	1.61	0.103	0.074	0.028	3.97
CO GM/MI	FORD	53	99	22.2	1.91	1.35	0.425	4.98
	VOLKS	20	99	25.4	2.54	1.29	0.405	4.22
NOX GM/MI	AMC	17	99	2.90	0.269	0.222	0.063	5.87
	PLYM	20	95	3.24	0.251	0.114	0.049	3.09
	DODGE	15	99	4.19	0.383	0.196	0.064	3.93
	FORD	53	99	3.66	0.172	0.129	0.027	3.08
	CHEV	47	99	2.84	0.104	0.127	0.027	3.80
	OLDS	12	95	2.78	0.080	0.207	0.072	5.74
	BUICK	16	99	2.35	0.108	0.076	0.019	2.37
	CADI	3	95	2.43	0.113	0.245	0.055	7.18

TABLE 32
MILEAGE EFFECTS FOR 1971 MODEL VEHICLES
DENVER ONLY

	MAKE	N	SIGNIFICANCE LEVEL %	INTERCEPT GM/MI MEAN	INTERCEPT GM/MI STANDARD ERROR	SLOPE GM/MI/1000MI MEAN	SLOPE GM/MI/1000MI STANDARD ERROR	% CHANGE 1000 MI
HC GM/MI	NONE							
CO GM/MI	AMC	20	95	74.2	8.82	-3.43	1.370	-5.67
	PLYM	20	95	77.0	7.49	-3.63	1.541	-5.81
	FORD	24	99	51.5	2.59	-2.66	0.531	-6.46
	CHEV	34	99	76.5	4.36	-5.65	0.998	-10.48
	PONT	5	99	46.0	6.84	-3.72	0.323	-11.95
	OLDS	6	99	56.5	6.92	-7.79	1.620	-22.00
	BUICK	9	95	60.6	9.91	-3.36	1.293	-7.11
	VOLKS	23	99	44.4	2.74	-2.15	0.554	-6.31
NOX GM/MI	CHEV	34	99	2.13	0.140	0.088	0.330	3.55
	OLDS	5	99	2.72	0.278	0.302	0.550	7.59

Table 33

SIX-CITY SURVEILLANCE PROGRAM—1957-1971 MODEL VEHICLES

OBJECTIVES:	DETERMINE CONTRIBUTION TO AIR POLLUTION BY VEHICLE POPULATION RESPONSIBLE FOR 95% OF VEHICLE EXHAUST EMISSION (CIRCA 1971); COLLECT EMISSIONS DATA DURING STEADY-STATE MODES, ACCEL/DECEL DRIVING CYCLE; EVALUATE CITY EFFECTS; COLLECT EVAPORATIVE EMISSIONS DATA.
BASIC TEST PROCEDURES:	1972 FTP (CVS-C) AND 1975 FTP (CVS-CH). IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 35, NO. 219, NOV. 10, 1970; VOL. 36, NO. 55, MARCH 20, 1971; VOL. 36, NO. 128, JULY 2, 1971. EACH VEHICLE TESTED ONCE (EXCEPT FOR SUBSET OF REPLICATES). EVAPORATIVE TESTS BY SHED TECHNIQUE (SAE J71). VEHICLES TESTED IN "AS-RECEIVED" CONDITION AND ANY MEASUREMENT OF IDLE SPEED TIMING, ETC. MADE ONLY AFTER VEHICLE TESTED.
INSTRUMENTATION	HC – FLAME IONIZATION ANALYZER CO, CO_2 – NON-DISPERSIVE INFRARED (NDIR) NO, NO_X – CHEMILUMINESCENT ANALYZER
CITIES:	HOUSTON, LOS ANGELES, DENVER, CHICAGO, ST. LOUIS, AND WASHINGTON, D. C.
TOTAL VEHICLES TESTED:	1020

Table 34

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1972 TEST PROCEDURES (EXCLUDING DENVER)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL †			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
PRE-68																	
57	20	80.0	0	10	40	7.07	2.32	6.72	1.39	80.3	33.2	73.5	1.57	3.89	2.15	3.24	1.98
58	20	86.7	5	5	50	10.74	10.65	8.58	1.81	85.2	38.6	78.5	1.85	3.70	2.44	2.92	2.14
59	21	79.7	0	19	33	11.37	8.70	9.19	1.89	81.6	45.0	70.7	1.74	4.47	2.39	3.71	1.99
60	16	65.4	13	13	50	9.53	8.48	7.40	2.01	86.8	44.8	75.0	1.80	3.94	2.37	3.26	1.94
61	23	67.6	17	17	61	6.49	3.64	5.69	1.67	84.6	59.8	66.5	2.06	3.12	2.25	2.53	1.97
62	38	72.7	5	8	40	9.57	6.87	7.83	1.88	95.5	38.8	77.5	1.60	3.34	1.57	2.93	1.75
63	56	77.3	0	2	47	10.26	8.11	8.85	1.62	105.8	41.9	98.1	1.49	3.63	2.15	3.07	1.81
64	64	72.1	0	3	42	8.14	3.70	7.49	1.49	91.0	41.4	82.3	1.60	3.61	1.71	3.19	1.70
65	80	62.9	1	4	53	12.17	13.29	9.24	1.89	97.9	40.7	90.0	1.52	3.27	1.66	2.87	1.70
66*	67	61.8	2	3	45	9.20	6.18	8.07	1.61	103.3	43.2	94.3	1.56	3.44	1.71	3.01	1.75
67*	54	54.6	0	2	46	8.19	3.61	7.51	1.51	103.5	47.7	94.5	1.54	3.26	1.45	2.90	1.71
TOTAL PRE 68*	458	68.5	2	5	46	9.56	8.06	8.02	1.70	95.2	43.5	85.6	1.61	3.51	1.87	3.01	1.79
CALIFORNIA																	
66	16	65.7	19	19	38	8.72	8.64	6.62	2.00	78.1	38.3	70.2	1.61	3.23	1.44	2.91	1.64
67	17	56.4	12	6	53	6.22	3.52	5.52	1.63	81.4	38.0	74.6	1.52	3.30	1.45	2.98	1.61
CONTROLLED																	
1968	84	46.4	20	25	35	6.25	7.10	5.13	1.70	78.6	59.0	63.8	1.86	4.22	1.88	3.75	1.69
1969	89	39.5	12	10	11	5.96	4.72	5.19	1.59	73.8	36.2	66.0	1.62	5.32	2.01	4.93	1.50
1970	86	28.7	30	33	9	4.41	2.18	4.06	1.47	56.5	27.2	50.2	1.66	4.93	1.64	4.66	1.41
1971	101	15.6	61	46	13	3.44	1.38	3.21	1.45	47.5	27.2	40.4	1.80	4.75	1.73	4.42	1.48
TOTAL 68-71	360	31.9	32	29	17	4.96	4.50	4.27	1.62	63.5	40.9	53.5	1.80	4.81	1.85	4.43	1.54

* EXCLUDING CALIFORNIA 66-67

† HC 3.4 gm/mi
CO 39.0 gm/mi
NO_{X_c} 3.0 gm/mi

Table 35

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1972 TEST PROCEDURE (DENVER ONLY)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL*			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
TOTAL PRE 68	97	65.1	0	1	83	11.31	6.13	10.27	1.51	136.8	55.5	125.8	1.53	1.93	1.11	1.66	1.76
1968	18	42.1	0	0	83	8.74	4.08	8.00	1.53	122.9	66.1	109.9	1.60	2.38	1.11	2.19	1.50
1969	17	38.9	12	6	65	7.74	4.89	6.49	1.89	92.6	57.7	79.7	1.72	2.52	1.21	2.20	1.78
1970	17	26.0	6	0	59	7.85	4.23	6.91	1.70	111.2	39.8	103.4	1.45	2.72	1.13	2.48	1.59
1971	20	15.1	0	5	55	6.80	2.08	6.52	1.35	102.7	40.6	94.5	1.54	3.06	1.56	2.75	1.59
TOTAL 68-71	72	30.1	4	3	65	7.73	3.89	6.93	1.62	106.4	52.0	95.6	1.59	2.68	1.28	2.41	1.62

* HC - 3.4 gm/mi
CO - 39.0 gm/mi
NO_{X_c} - 3.0 gm/mi

Table 36

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1975 TEST PROCEDURES (EXCLUDING DENVER)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL †			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
PRE-68																	
57	20	80.0	0	5	40	6.83	2.32	6.25	1.42	81.4	30.7	75.6	1.50	3.83	2.19	3.17	1.99
58	20	86.7	5	10	45	10.03	10.20	7.93	1.84	78.2	36.8	69.7	1.67	3.62	2.31	2.88	2.12
59	21	79.7	0	19	38	10.80	8.24	8.70	1.88	77.3	45.9	65.8	1.79	4.49	2.55	3.61	2.08
60	16	65.4	13	19	56	8.79	8.09	6.82	1.98	81.6	43.4	70.0	1.83	3.94	2.48	3.18	2.02
61	23	67.6	26	17	61	5.94	3.27	5.20	1.68	79.7	56.8	61.8	2.12	3.06	2.35	2.43	2.04
62	38	72.7	5	8	49	8.87	6.84	7.09	1.94	78.0	38.6	69.6	1.67	3.33	1.57	2.91	1.76
63	55	77.3	0	2	53	9.43	7.76	8.04	1.65	96.5	38.4	89.2	1.50	3.64	2.15	3.08	1.82
64	64	72.1	2	13	39	7.28	3.29	6.68	1.50	81.7	38.8	73.1	1.64	3.66	1.77	3.24	1.68
65	80	62.9	0	3	49	11.18	12.62	8.36	1.92	87.9	36.8	80.8	1.51	3.37	1.66	2.97	1.70
66*	67	61.8	5	10	42	8.26	5.48	7.21	1.63	91.0	38.9	82.3	1.60	3.57	1.82	3.13	1.72
67*	54	54.6	2	6	48	7.38	3.28	6.75	1.52	93.6	44.9	85.1	1.55	3.28	1.46	2.93	1.68
TOTAL PRE 68*	458	68.5	4	8	46	8.74	7.63	7.26	1.73	86.5	40.3	77.4	1.63	3.54	1.91	3.04	1.79
CALIFORNIA																	
66	16	65.7	19	25	31	7.84	8.34	5.81	2.03	65.2	36.6	56.8	1.72	3.40	1.54	3.04	1.68
67	17	56.4	24	12	41	5.33	3.52	4.60	1.70	67.2	37.0	59.7	1.63	3.42	1.50	3.08	1.65
CONTROLLED																	
1968	84	46.4	31	34	26	5.54	7.07	4.45	1.73	67.8	57.5	52.7	1.96	4.34	1.92	3.85	1.71
1969	89	39.5	20	21	10	5.19	4.26	4.53	1.56	61.7	31.0	55.0	1.63	5.45	2.02	5.06	1.49
1970	86	28.7	41	44	11	3.90	1.95	3.60	1.46	48.2	24.7	42.0	1.72	5.05	1.67	4.78	1.40
1971	101	15.6	70	60	15	3.06	1.26	2.85	1.44	40.1	24.5	33.5	1.86	4.81	1.78	4.47	1.49
TOTAL 68-71	360	31.9	42	40	15	4.37	4.30	3.75	1.61	53.9	37.9	44.4	1.86	4.92	1.88	4.52	1.54

* EXCLUDING CALIFORNIA 66-67

† HC 3.4 gm/mi
CO 39.0 gm/mi
NO_{X_c} 3.0 gm/mi

Table 37

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1975 TEST PROCEDURE (DENVER ONLY)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL*			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
TOTAL PRE 68	97	65.1	0	0	83	10.16	5.59	9.24	1.49	126.9	48.5	117.4	1.51	1.89	1.12	1.61	1.79
1968	18	42.1	0	0	83	7.34	2.73	6.87	1.46	109.2	52.5	99.7	1.53	2.20	0.80	2.07	1.43
1969	17	38.9	18	12	65	6.31	3.47	5.43	1.84	76.4	47.7	65.6	1.74	2.59	1.24	2.27	1.76
1970	17	26.0	12	0	53	6.71	3.85	5.93	1.66	94.8	33.8	89.3	1.43	2.78	1.11	2.55	1.57
1971	20	15.1	5	5	50	5.68	1.45	5.51	1.29	91.1	37.6	83.1	1.58	3.08	1.60	2.75	1.62
TOTAL 68-71	72	30.1	8	4	63	6.46	2.97	5.89	1.57	92.2	43.7	83.0	1.60	2.67	1.25	2.40	1.61

* HC 3.4 gm/mi
CO 39.0 gm/mi
NO_{X_c} 3.0 gm/mi

Table 38

EMISSION LEVELS AS AFFECTED BY GEOGRAPHIC LOCATION
1972 AND 1975 CVS TEST PROCEDURES

YEAR	N	MEAN MILES (K)	HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{x_2} gm/mi			
			72* MEAN[1]	72* SD	75+ MEAN	75+ SD	72 MEAN	72 SD	75 MEAN	75 SD	72 MEAN	72 SD	75 MEAN	75 SD
PRE CONTROL EXCLUDING DENVER	468	68.5	9.56	8.06	8.74	7.63	86.2	46.4	86.5	40.3	3.61	1.87	3.64	1.91
PRE CONTROL DENVER	97	65.1	11.31	6.13	10.16	5.59	135.8	56.5	126.9	48.6	1.93	1.11	1.89	1.12
CONTROLLED[2] EXCLUDING DENVER	383	34.3	5.16	4.50	4.54	4.30	64.8	41.0	54.9	38.0	4.77	1.88	4.78	1.98
CONTROLLED DENVER	72	30.1	7.73	3.89	6.46	2.97	106.4	52.0	92.2	43.7	2.68	1.28	2.67	1.25

(1) ARITHMATIC MEAN & SD

(2) INCLUDES 1966, 1967, LOS ANGELES

* 72 TEST PROCEDURE

+ 75 TEST PROCEDURE

Table 39
EMISSION LEVELS BY VEHICLE WEIGHT AS DETERMINED BY 1975 TEST PROCEDURE EXCLUDING DENVER AND DENVER ONLY

EXCLUDING DENVER

		HC-gm/mi		CO-gm/mi		NO_{xc} gm/mi	
		ARITHMETIC		ARITHMETIC		ARITHMETIC	
VEHICLE WEIGHT (1b)	N	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1501 - 2000	54	6.70	5.2	52.53	23.30	2.53	1.5
2001 - 2500	33	3.67	2.6	42.31	28.70	3.76	2.0
2501 - 3000	132	6.35	7.4	62.51	36.80	3.89	1.8
3001 - 3500	192	6.88	6.9	73.70	40.6	4.00	1.9
3501 - 4000	263	7.91	7.7	80.33	47.1	4.09	2.0
4001 - 4500	141	5.96	3.7	74.48	40.1	4.99	2.0
4501 - 5000	31	6.39	8.5	84.81	48.8	4.85	2.4
5001 - 5500	5	5.69	3.4	64.40	37.6	5.98	2.1

DENVER

		HC-gm/mi		CO-gm/mi		NO_{xc} gm/mi	
		ARITHMETIC		ARITHMETIC		ARITHMETIC	
VEHICLE WEIGHT (1b)	N	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1501 - 2000	12	6.16	1.9	78.12	16.9	1.19	0.4
2001 - 2500	5	5.11	3.6	48.15	19.3	2.14	1.3
2501 - 3000	23	7.67	3.3	106.52	37.7	1.94	1.1
3001 - 3500	48	8.57	3.7	103.00	42.9	2.31	1.3
3501 - 4000	56	9.89	6.7	124.24	52.2	2.37	1.3
4001 - 4500	19	9.32	4.9	140.61	60.3	2.42	1.1
4501 - 5000	4	5.34	1.5	108.16	45.9	2.67	0.5
5001 - 5500	2	5.04	1.9	155.20	30.8	2.32	1.2

Table 40
ACCELERATION/DECELERATION MODES AND DRIVING SEQUENCE

MODE			TIME IN MODE (sec)	AVERAGE SPEED (mph)	AVERAGE ACCEL-ERATION RATE (mph/sec)	DISTANCE (miles)
NO.	TYPE	SPEED RANGE (mph)				
1	ACCEL	0-30	12	18.05	2.50	0.0602
2	DECEL	30-0	16	16.66	-1.88	0.0741
3	ACCEL	0-15	8	9.04	1.88	0.0201
4	ACCEL	15-30	11	23.07	1.36	0.0705
5	ACCEL	30-45	13	37.65	1.15	0.1360
6	DECEL	45-30	12	38.05	-1.25	0.1268
7	ACCEL	30-60	17	45.80	1.76	0.2163
8	DECEL	60-45	12	53.01	-1.25	0.1716
9	ACCEL	45-60	14	52.54	1.07	0.2043
10	DECEL	60-15	30	40.40	-1.50	0.3367
11	ACCEL	15-60	26	43.42	1.73	0.3136
12	DECEL	60-0	21	33.83	-2.80	0.1973
13	ACCEL	0-60	32	38.24	1.88	0.3313
14	DECEL	60-30	23	46.86	-1.30	0.2994
15	DECEL	30-15	9	23.18	-1.67	0.0579
16	DECEL	15-0	8	7.81	-1.88	0.0173
17	ACCEL	0-45	22	28.85	2.05	0.1759
18	DECEL	45-15	16	31.33	-1.88	0.1392
19	ACCEL	15-45	18	30.55	1.67	0.1528
20	DECEL	45-0	19	24.72	-2.37	0.1304
21	ACCEL	0-60	25	38.28	2.40	0.2654
22	DECEL	60-0	28	33.88	-2.14	0.2634
23	ACCEL	0-30	15	17.73	2.00	0.0737
24	ACCEL	30-60	25	45.14	1.20	0.3134
25	DECEL	60-30	18	47.23	-1.67	0.2362
26	DECEL	30-0	10	15.99	-3.00	0.0444
27	ACCEL	0-60	38	38.01	1.58	0.4009
28	DECEL	60-0	35	33.87	-1.71	0.3293
29	ACCEL	0-30	18	17.73	1.67	0.0886
30	ACCEL	30-60	21	45.27	1.43	0.2599
31	DECEL	60-30	14	46.63	-2.14	0.1813
32	DECEL	30-0	13	16.40	-2.31	0.0592

Table 41

MEAN EMISSIONS DATA FOR 32 ACCELERATION/DECELERATION MODES

(FIVE CITIES EXCLUDING DENVER - 851 TESTS)

	(PPM) CONCENTRATION				(GRAMS PER MILE) MASS			
MODE	HC	CO	CO2	NOX*	HC	CO	CO2	NOX*
1	757.	3773.	19118.	212.	11.8	121.28	955.38	11.3
2	353.	1390.	6111.	41.	5.6	46.75	310.77	2.3
3	536.	2997.	10928.	62.	16.2	190.38	1060.35	6.4
4	555.	2917.	17471.	183.	6.6	72.53	674.88	7.5
5	650.	2973.	24090.	328.	4.7	45.18	573.36	8.3
6	399.	1500.	8440.	95.	2.8	22.18	192.40	2.4
7	981.	7148.	33971.	426.	6.0	90.48	669.26	8.9
8	542.	2140.	12572.	171.	2.9	23.69	216.33	3.1
9	847.	4126.	32846.	493.	4.5	45.27	564.19	9.0
10	610.	1953.	9234.	106.	4.2	27.44	198.57	2.5
11	952.	6098.	31886.	445.	6.1	81.23	662.80	9.8
12	600.	1912.	8590.	103.	4.9	32.04	219.98	2.9
13	925.	5335.	29772.	436.	6.9	82.74	721.16	11.2
14	616.	2082.	10019.	115.	3.6	25.29	187.35	2.3
15	375.	1522.	6338.	40.	4.3	36.85	231.41	1.6
16	344.	1902.	5241.	21.	11.7	138.53	562.57	2.4
17	806.	4649.	23429.	298.	7 8	93.16	730.27	9.9
18	449.	1775.	7317.	67.	3.9	32.10	200.71	2.0
19	741.	4334.	23069.	292.	6.7	81.70	677.77	9.1
20	459.	1798.	6915.	59.	5.0	41.18	239.54	2.2
21	1073.	7789.	31467.	402.	7.9	118.07	742.47	10.1
22	629.	1995.	8257.	86.	5.1	33.48	211.49	2.4
23	709.	3691.	17115.	182.	11.1	120.15	861.83	9.8
24	795.	4510.	29170.	431.	4.9	57.59	582.50	9.1
25	584.	2041.	9910.	118.	3.4	24.52	183.55	2.4
26	382.	1646.	6142.	39.	6.4	58.05	324.64	2.2
27	830.	4625.	27380.	409.	6.1	70.34	649.38	10.3
28	612.	2062.	8208.	78.	5.0	34.65	209.93	2.2
29	643.	3504.	15556.	155.	10.0	113.70	779.45	8.3
30	850.	5851.	30179.	410.	5.3	75.95	610.55	8.8
31	546.	2006.	9896.	129.	3.2	24.42	185.34	2.6
32	403.	1768.	5871.	37.	6.6	60.83	300.49	2.1

*UNCORRECTED FOR HUMIDITY

Table 42

MEAN EMISSIONS DATA FOR 32 ACCELERATION/DECELERATION MODES (DENVER - 169 TESTS)

	(PPM) CONCENTRATION				(GRAMS PER MILE) MASS			
MODE	HC	CO	CO_2	NO_x*	HC	CO	CO_2	NO_x*
1	1003	10450	14172	112	12.7	271.66	564.54	4.6
2	446	2458	4902	37	6.0	69.07	200.92	1.5
3	660	5252	7915	33	16.6	272.49	616.48	2.5
4	740	7279	12806	106	7.3	147.87	397.75	3.4
5	919	10626	18105	212	5.6	132.00	346.72	4.2
6	508	3041	6759	95	3.0	37.49	124.06	1.8
7	1498	22506	23961	230	7.5	230.14	379.42	3.8
8	786	4984	10286	188	3.5	45.41	142.23	2.8
9	1274	16440	24223	341	5.6	146.63	334.63	4.9
10	835	4093	7619	124	4.7	47.48	132.40	2.3
11	1572	23397	22522	199	8.3	252.75	376.35	3.5
12	833	4085	7314	123	5.6	56.54	151.35	2.7
13	1535	19753	20438	198	9.5	248.87	397.62	4.0
14	895	4857	8680	139	4.4	48.60	130.85	2.2
15	511	2826	5082	44	5.0	56.95	149.68	1.3
16	451	2982	3866	17	13.0	179.61	332.14	1.3
17	1265	16247	15999	133	10.1	264.70	400.57	3.5
18	604	3524	5945	69	4.4	52.77	131.49	1.6
19	1126	14863	15766	128	8.4	228.05	371.59	3.1
20	630	3491	5530	59	5.8	66.23	154.21	1.7
21	1730	25496	21238	156	10.4	312.80	402.57	3.1
22	850	4555	7479	102	5.7	63.09	155.03	2.2
23	1045	10461	12261	94	13.5	277.35	496.14	3.9
24	1246	17567	19730	203	6.3	182.49	316.22	3.4
25	745	5084	8719	146	3.6	50.38	130.23	2.3
26	502	2813	4857	42	7.1	82.31	206.87	1.8
27	1346	17466	18799	191	8.1	215.80	358.05	3.8
28	850	4514	7061	99	5.7	62.49	145.87	2.2
29	894	8897	11108	93	11.5	235.36	446.97	3.9
30	1468	20384	20620	188	7.6	214.38	334.98	3.2
31	760	4978	8493	150	3.7	49.99	128.43	2.4
32	551	2866	4501	37	7.6	81.72	185.66	1.5

*UNCORRECTED FOR HUMIDITY

Table 43

MEAN EMISSIONS DATA FOR FIVE STEADY STATE MODES[1]

CITY	POLLUTANT	IDLE	15 mph	30 mph	45 mph	60 mph
LOS ANGELES	HC	1.45	5.28	3.09	2.91	2.60
	CO	17.02	69.11	29.50	24.60	25.51
	CO_2	72.32	409.53	333.12	357.90	372.47
	NO_x^2	0.08	0.51	1.69	3.78	5.51
DENVER	HC	1.47	6.06	3.74	3.94	3.87
	CO	17.20	86.49	52.13	56.43	71.13
	CO_2	60.54	345.92	297.92	330.09	368.91
	NO_x^2	0.12	0.83	1.53	3.07	4.52
CHICAGO	HC	1.30	5.47	3.48	3.59	3.62
	CO	15.49	66.57	29.77	30.53	32.63
	CO_2	63.85	358.70	318.61	357.65	417.11
	NO_x^2	0.10	0.87	2.36	4.37	6.26
HOUSTON	HC	1.50	5.68	3.02	2.83	2.47
	CO	18.74	77.29	35.11	32.38	31.71
	CO_2	76.13	391.06	318.01	356.13	404.79
	NO_x^2	0.14	0.83	1.49	3.47	5.70
ST. LOUIS	HC	1.33	4.90	2.76	2.58	2.67
	CO	16.43	67.68	29.54	26.13	26.97
	CO_2	64.28	334.24	301.64	315.26	362.26
	NO_x^2	0.08	0.53	1.57	3.38	5.43
WASHINGTON	HC	1.12	4.23	2.59	2.57	2.88
	CO	13.25	56.10	26.19	25.40	25.79
	CO_2	65.04	380.44	343.54	390.83	452.50
	NO_x^2	0.13	1.04	2.88	6.04	8.90
ALL EXCEPT DENVER	HC	1.34	5.11	2.99	2.90	2.85
	CO	16.19	67.36	30.02	27.79	28.50
	CO_2	68.35	374.23	323.03	355.55	401.60
	NO_x^2	0.11	0.75	2.00	4.21	6.35

1. IDLE RESULTS IN GRAMS PER MINUTE. NO_x NOT CORRECTED FOR HUMIDITY. STEADY STATE RESULTS IN GRAMS PER MILE.

Table 44

FUEL EVAPORATIVE EMISSIONS USING THE ENCLOSURE TECHNIQUE

MODEL YEAR	N	DIURNAL MEAN* HC–GMS	S.D.	HOT SOAK MEAN* HC–GMS	S.D.	COMBINED MEAN* HC–GMS	S.D.
- LOS ANGELES -							
1957	2	33.04	12.31	22.04	8.14	55.08	20.45
1958	4	14.10	4.46	11.21	9.61	25.32	6.56
1959	4	40.49	48.79	11.03	5.66	51.52	52.99
1960	2	31.33	10.63	13.32	2.76	44.64	13.40
1961	4	11.94	1.80	13.86	4.86	25.80	5.73
1962	5	15.42	6.37	9.86	2.92	25.28	6.35
1963	7	27.37	27.75	18.33	15.19	45.71	31.42
1964	9	29.43	13.02	15.76	9.47	45.14	15.50
1965	11	43.36	31.56	15.04	6.48	58.39	30.20
1966	13	22.83	10.51	15.94	8.43	30.77	17.19
1967	10	25.56	20.40	15.22	8.04	41.78	23.93
1968	11	15.18	3.51	12.54	6.55	27.72	7.92
1969	13	26.34	11.62	15.10	5.66	41.44	11.61
1970	11	18.20	12.19	10.49	5.46	28.68	16.47
1971	20	15.22	10.74	11.15	6.86	26.37	15.90
1957-1971	126	23.67	18.79	13.75	7.68	37.41	21.69
- DENVER -							
1971	20	47.20	36.08	34.77	24.25	81.97	42.49

*ARITHMETIC MEAN

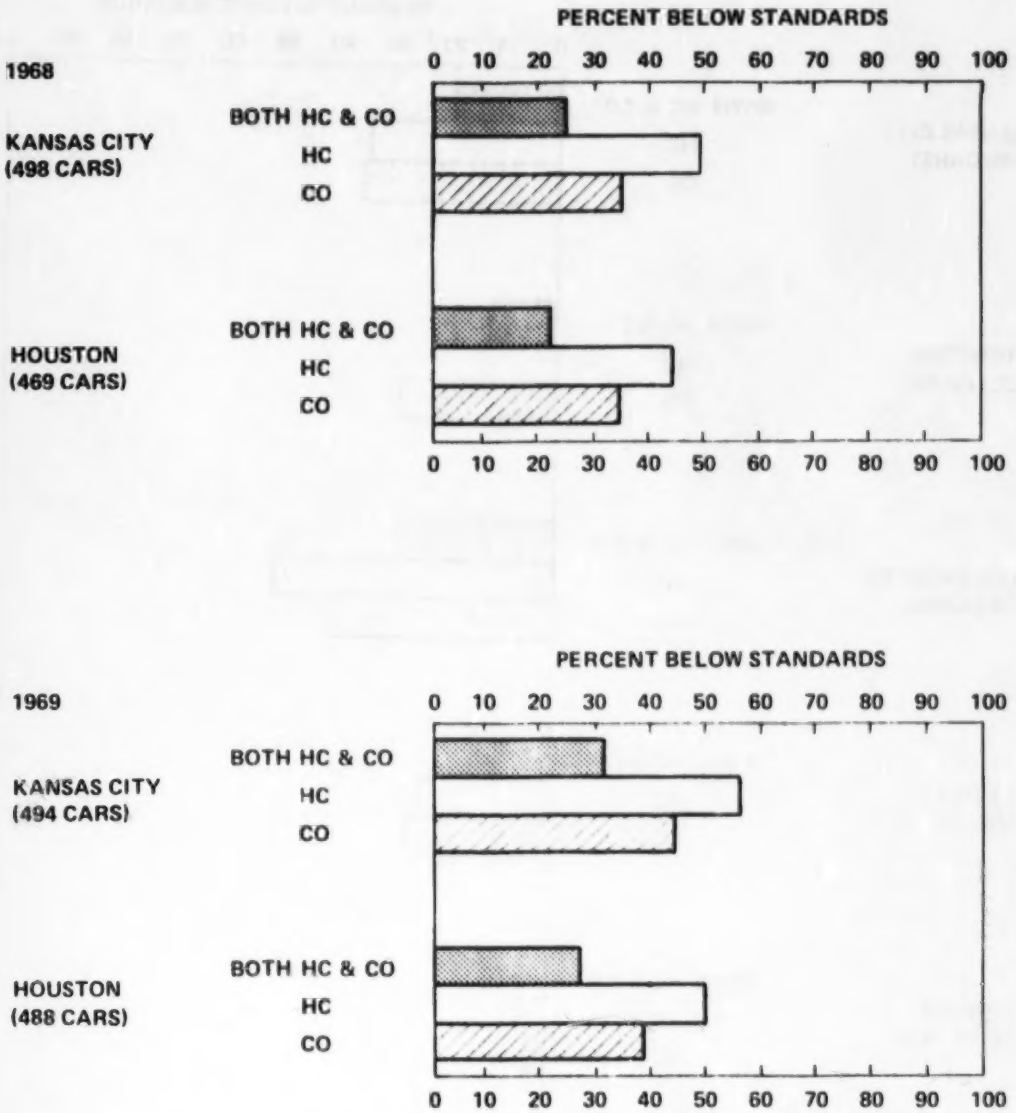

Figure 1 CONFORMANCE OF 1968 AND 1969 MODEL TEST FLEETS WITH EMISSION STANDARDS (COLD START SEVEN MODE, SEVEN CYCLE FEDERAL TEST PROCEDURE)

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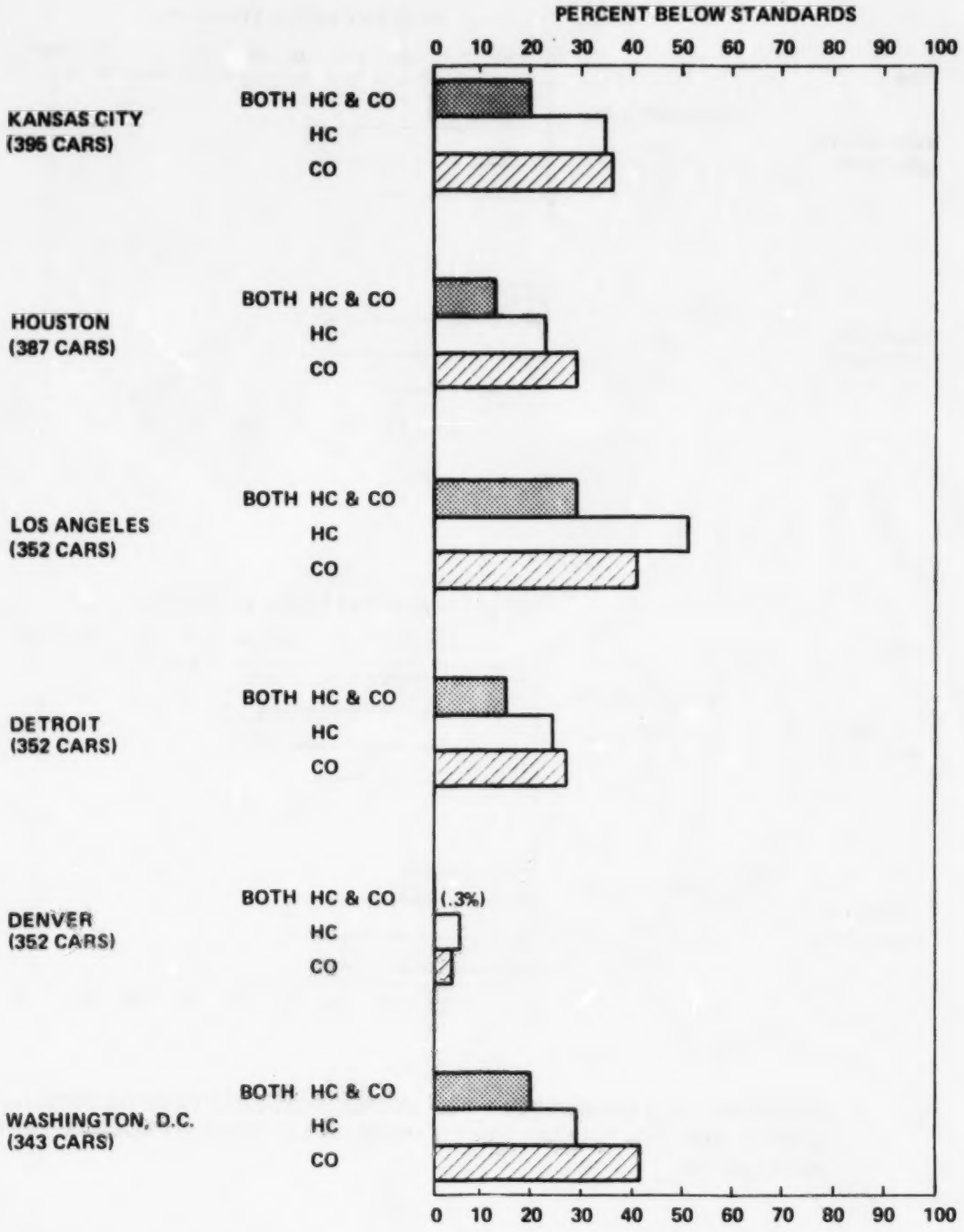

Figure 2 CONFORMANCE OF 1970 MODEL TEST FLEET WITH EMISSION STANDARDS (COLD START SEVEN MODE, SEVEN CYCLE FEDERAL TEST PROCEDURE)

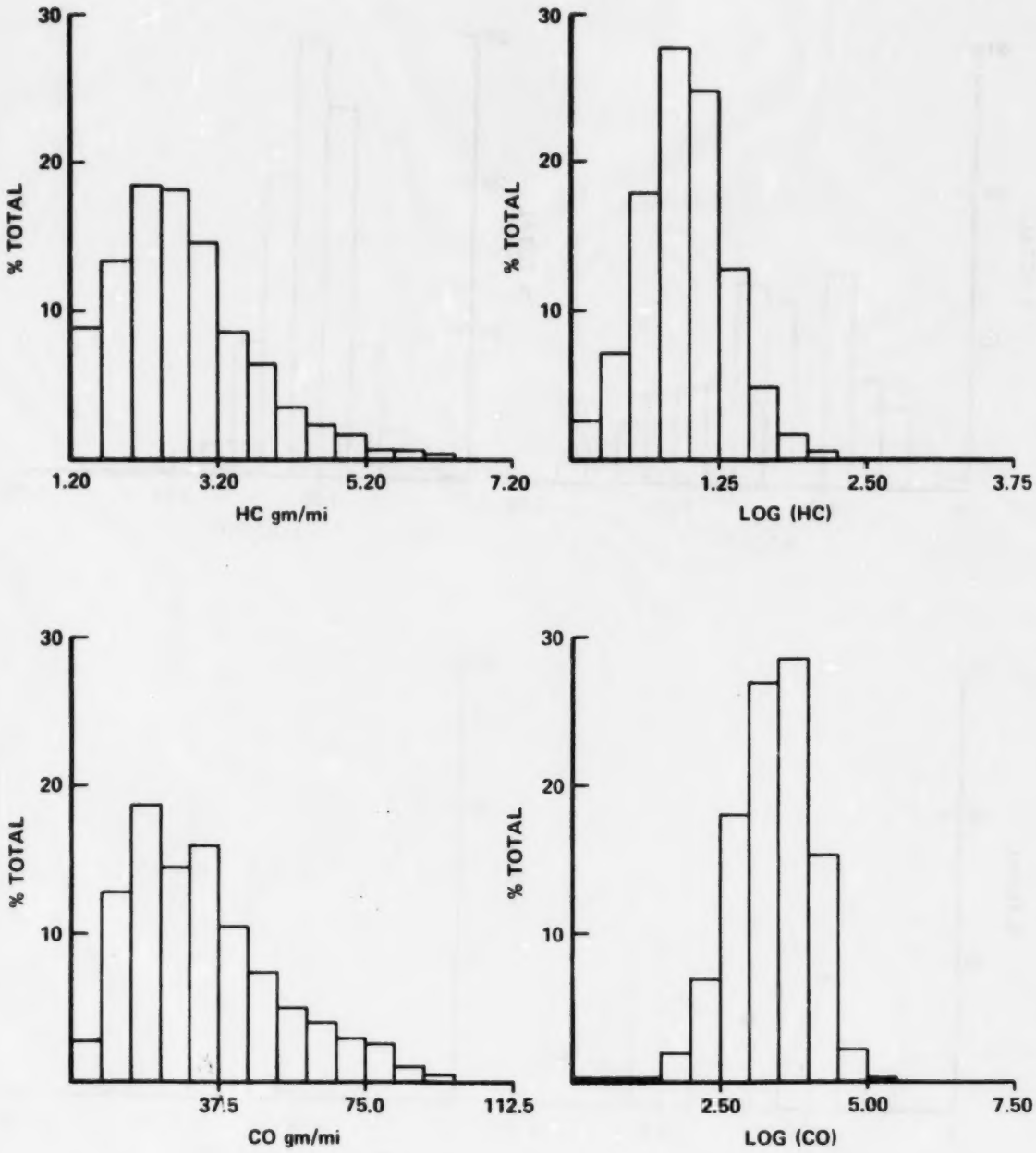

Figure 3 HISTOGRAMS OF HC AND CO EMISSIONS 1970 MODEL VEHICLES EXCLUDING DENVER

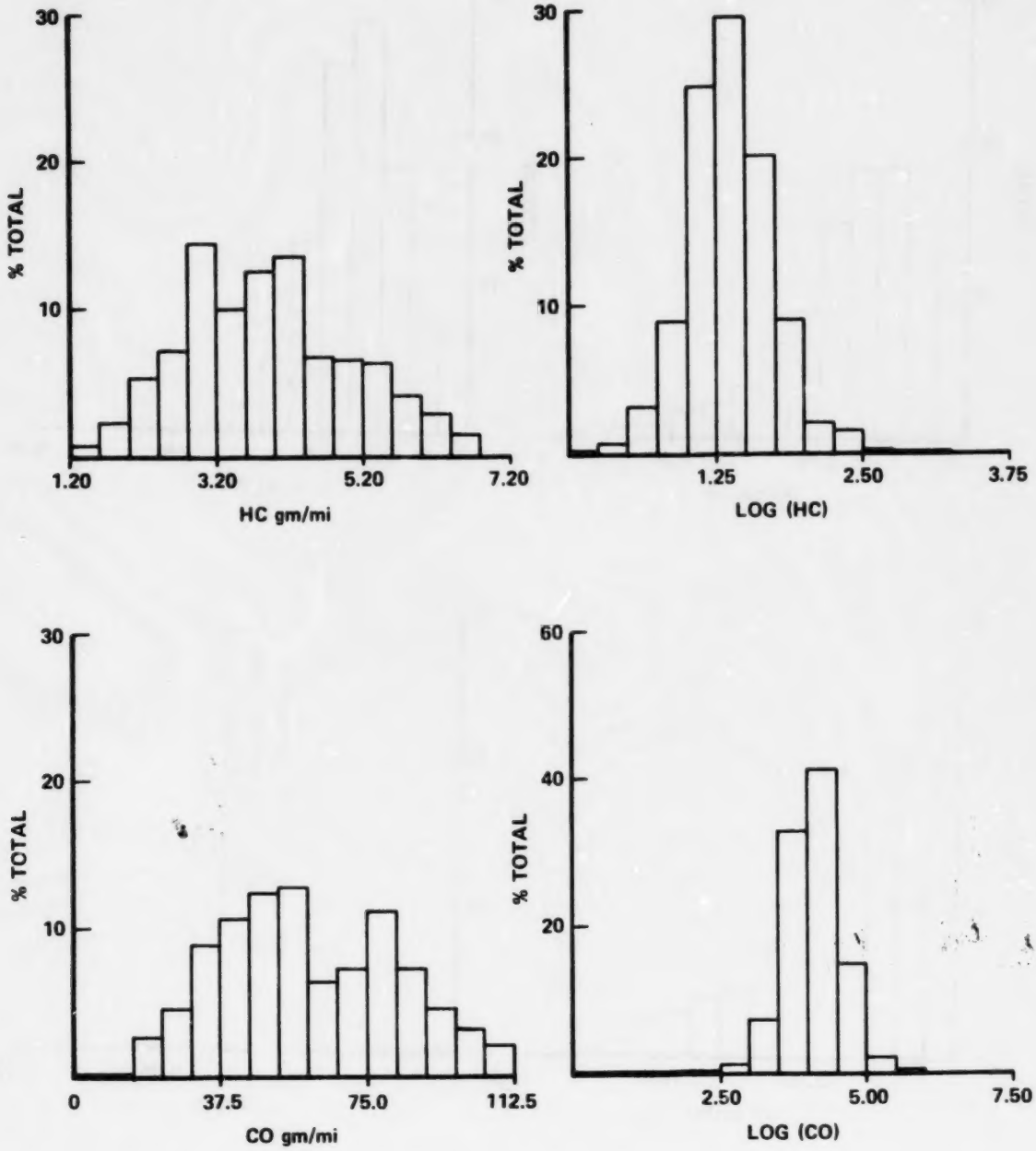

Figure 4 HISTOGRAMS OF HC AND CO EMISSIONS 1970 MODEL VEHICLES DENVER ONLY

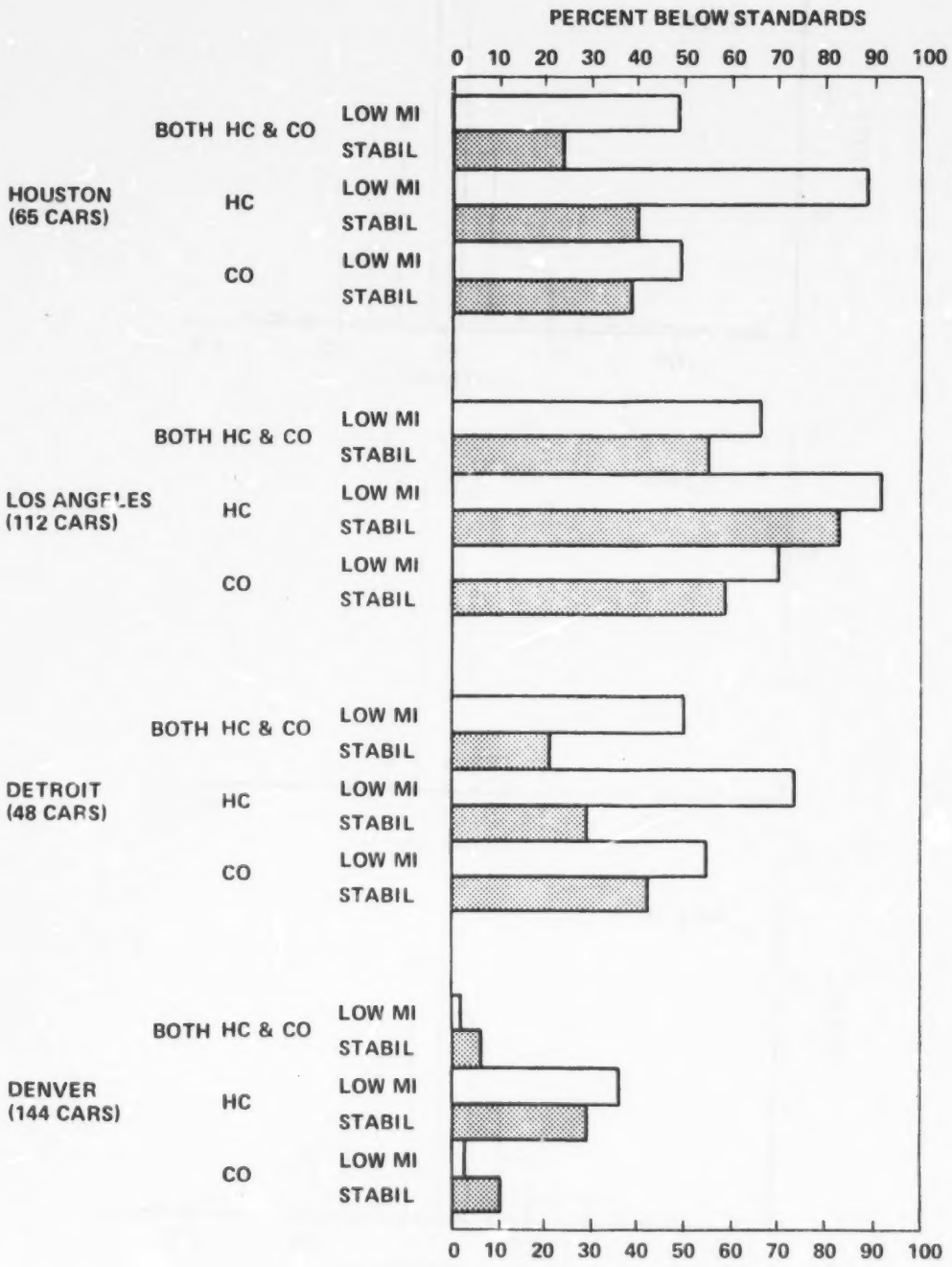

Figure 5 CONFORMANCE OF 1971 MODEL TEST FLEET WITH EMISSION STANDARDS (COLD START SEVEN MODE, SEVEN CYCLE TEST PROCEDURE)

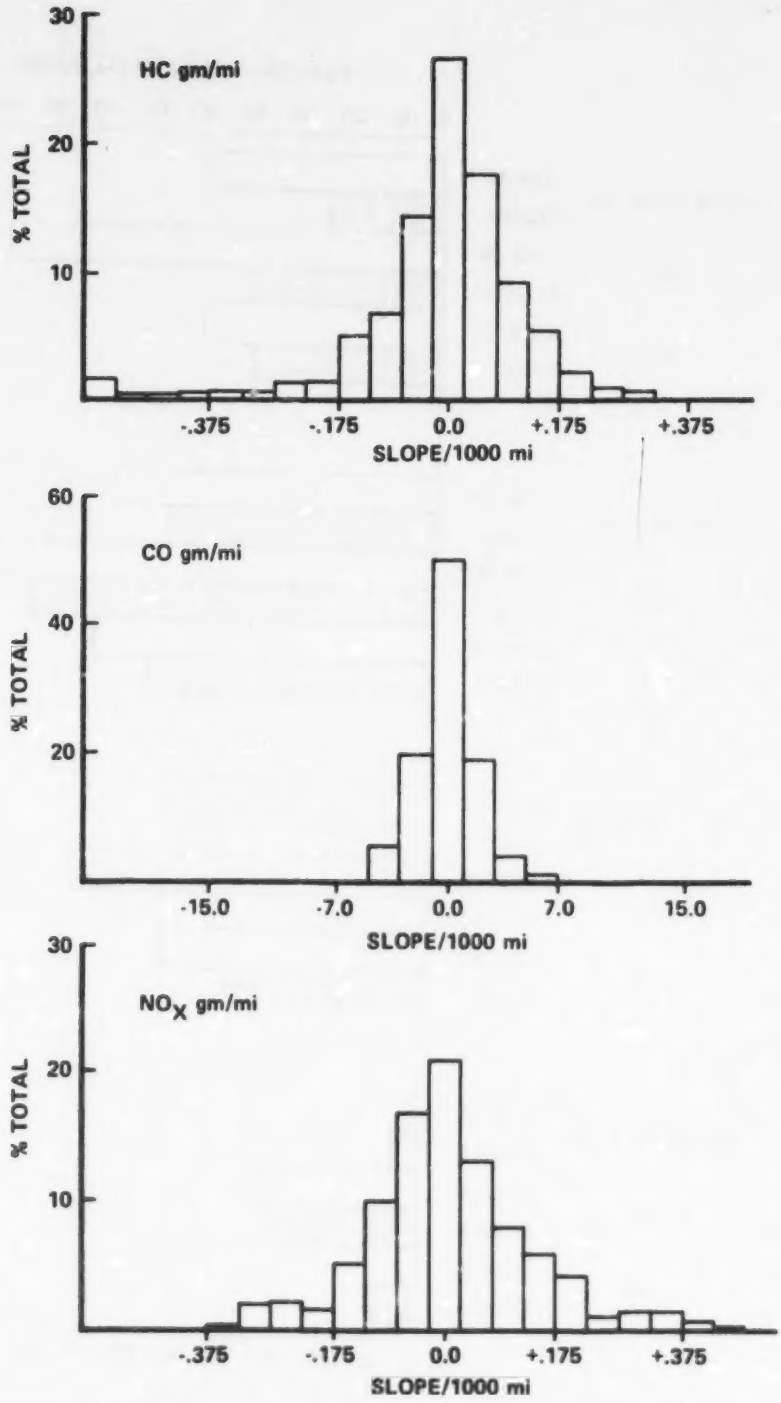

Figure 6 MILEAGE EFFECTS (HISTOGRAM OF SLOPES) 1968 MODEL VEHICLE

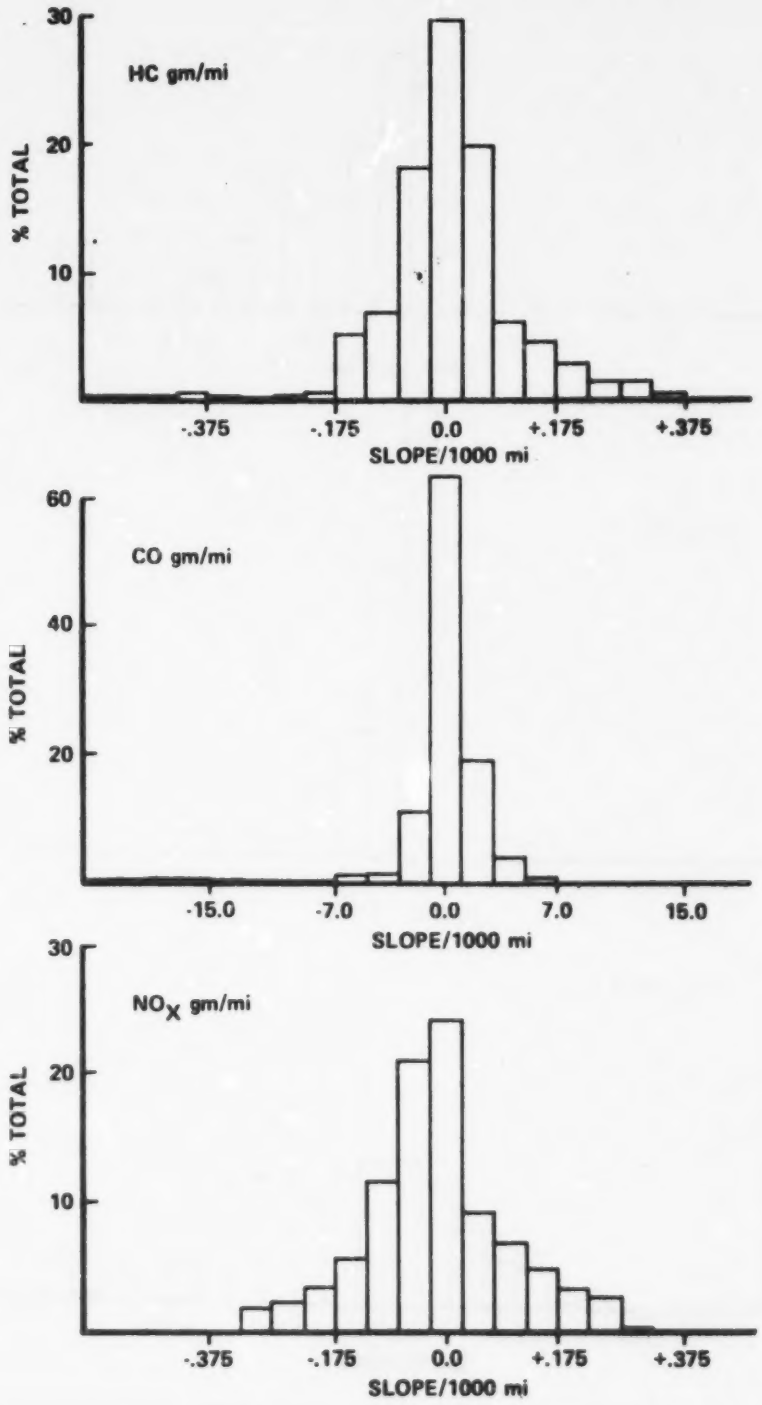

Figure 7 MILEAGE EFFECTS (HISTOGRAM OF SLOPES) 1989 MODEL VEHICLES

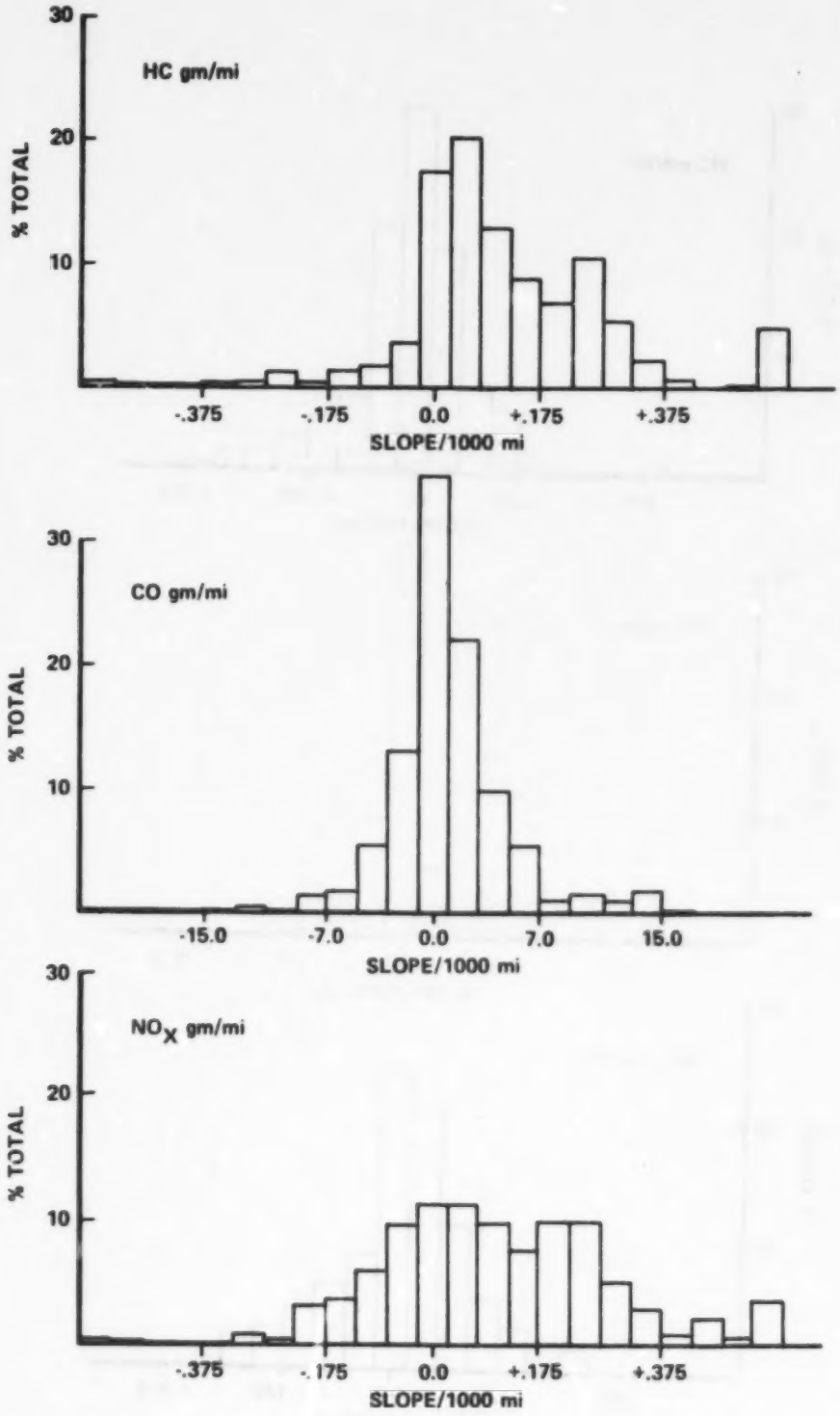

Figure 8 MILEAGE EFFECTS (HISTOGRAM OF SLOPES) 1971 MODEL VEHICLES – EXCLUDING DENVER

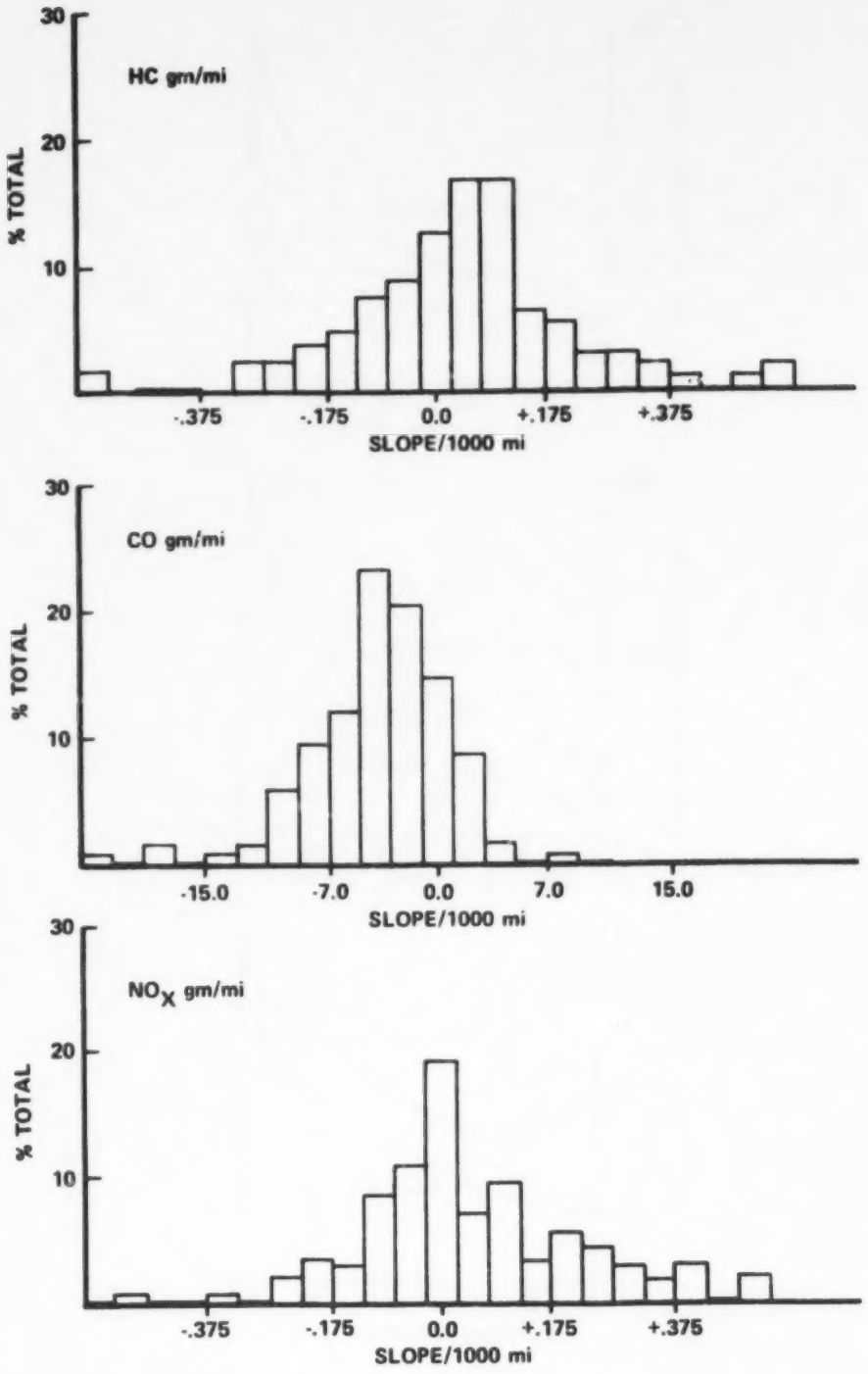

Figure 9 MILEAGE EFFECTS (HISTOGRAM OF SLOPES) 1971 MODEL VEHICLES DENVER

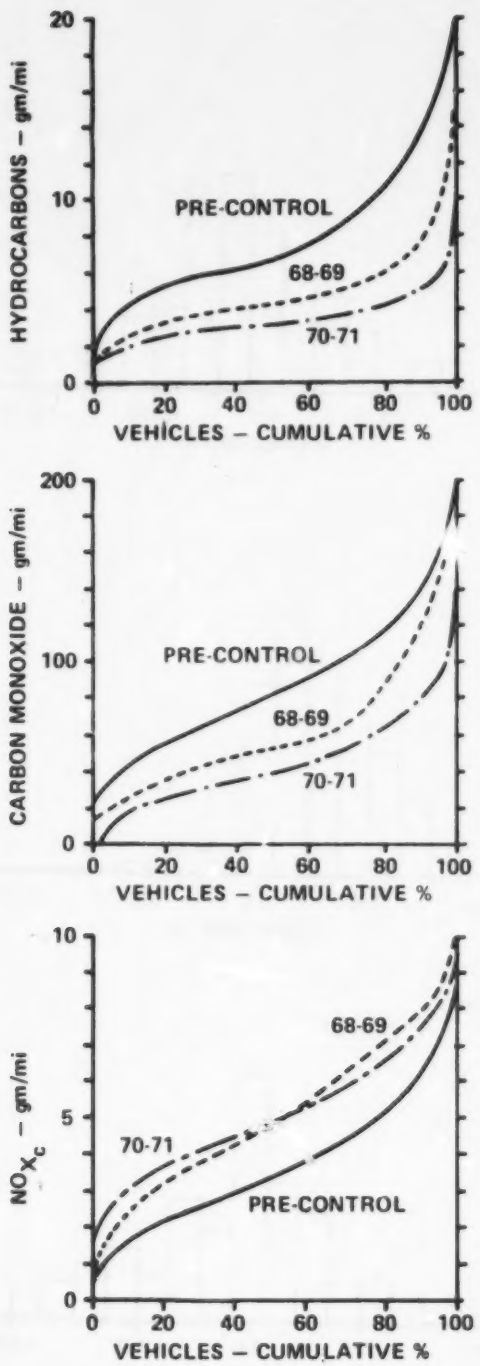

Figure 10 1975 CVS EMISSION LEVELS VS. CUMULATIVE PERCENTAGE OF TEST VEHICLES FOR PRE-CONTROL, 68-69 AND 70-71 MODEL YEARS (ALL CITIES EXCLUDING DENVER)

Appendix I

EMISSION REDUCTION GOAL--CALCULATIONS

The table on page 2 which shows the percent of the emission reduction goal that has been achieved is based on the Study of Light-Duty Vehicles in the Six Cities--1957-1971 Model-Year Survey. As explained in the text, a significant difference exists between Denver and the other five cities (Los Angeles, St. Louis, Houston, Chicago and Washington, D.C.). Vehicles tested in Denver, as well as 1966 and 1967 model year vehicles tested in Los Angeles which had been subject to California standards, were excluded from the calculations on which the table is based.

The table is based on 818 vehicle exhaust tests. The percent of goal achieved was determined as follows:

$$\text{Percent of Goal Achieved}_{HC} = \frac{\text{Pre-Cont}_{HC} \text{ Minus Actual}_{HC}}{\text{Pre-Cont}_{HC} \text{ Minus Std}_{HC}}$$

$$\text{Percent of Goal Achieved}_{CO} = \frac{\text{Pre-Cont}_{CO} \text{ Minus Actual}_{CO}}{\text{Pre-Cont}_{CO} \text{ Minus Std}_{CO}}$$

where:

$\text{Pre-Controlled}_{HC}$ = 9.56 gm/mi (this is the mean of HC emissions from pre-controlled cars tested in 1971, mean mileage = 68,500)

$\text{Pre-Controlled}_{CO}$ = 95.2 gm/mi (this is the mean of CO emissions from pre-controlled cars tested in 1971, mean mileage = 68,500)

Actual Emissions = the mean emission value measured for the model-year in question.

Std_{HC} = 3.4 gm/mi (this is the 1972 Federal standard)

Std_{CO} = 39.0 gm/mi (this is the 1972 Federal standard)

Appendix II

THE LOG-NORMAL DISTRIBUTION AS A STATISTICAL MODEL FOR EXHAUST EMISSIONS

Histograms compiled from automobile exhaust emission surveillance data suggest that these emissions conform to a log-normal distribution. In the following discussion, this distribution and its properties are examined and assumptions which might give rise to the distribution in an emissions context are explored.

1. PROPERTIES OF THE LOG-NORMAL DISTRIBUTION

A random variable X is said to have a log-normal distribution if log X has a normal distribution. Let Y = log X. Then Y has the probability density function

$$f(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-m}{\sigma}\right)^2}$$

where m and σ are, respectively, the mean and standard deviation of the random variable Y. Note that, with regard to the initial random variable X, m is the mean value of log X and σ is the standard deviation of log X.

Suppose, now, that one performs the inverse logarithmic transformation on m. It can be readily shown that antilog m is the geometric mean of the random variable X. Note, also, that the distribution of Y is symmetric. Therefore, m is not only the mean value of Y but also its median--that is, 50% of the values of Y are larger than m and 50% are smaller than m. It follows, therefore, that the antilog of m is the median for the distribution of X as well as being its geometric mean.

Interpretation of the standard deviation σ and its antilogarithm is somewhat more subtle. As long as one deals with Y, the log-transformed variable, interpretation of its distribution follows all the conventions normally employed in drawing inferences on the basis of the normal distribution. For example, if one adds the standard deviation to the mean, the result $M + \sigma$ is a value of Y below which approximately 84% of all the values of Y fall--that is, $m + \sigma$ is approximately the 84th percentile of the distribution. It follows, therefore, that antilog $(m + \sigma)$ is approximately the 84th percentile for the distribution of the original variable X. Similarly, if one adds two standard deviations to obtain $m + 2\sigma$, then $m + 2\sigma$ constitutes approximately the 95th percentile for the random variable Y and antilog $(m + 2\sigma)$ constitutes approximately the 95th percentile for the random variable X.

Consider, now, the inverse logarithm of σ . This quantity, antilog σ , retains the interpretational properties of σ provided it is used in a multiplicative rather than an additive sense. If antilog m (the median of X) is multiplied by antilog σ , the result is clearly antilog $(m + \sigma)$; therefore, the multiplication yields directly the 84th percentile of the random variable X. Similarly, if one multiplies the median of X by σ^2 , the result is clearly antilog $(m + 2\sigma)$, or the 95th percentile of X. It is for this reason that antilog σ is sometimes referred to as the "ratio standard deviation" in dealing with the log-normal distribution. In this report it is called the geometric standard deviation to connote its relation to the geometric mean.

2. A HEURISTIC JUSTIFICATION OF THE LOG-NORMAL DISTRIBUTION OF EMISSIONS

If emission measurements tend to follow a log-normal distribution, it is of interest to ask why this relationship holds.

A statistical process may tend toward producing a log-normal distribution if the following conditions are met:

(a) Several sources of error or variability combine in generating the random variable under study.

(b) These sources of error combine multiplicatively rather than additively.

Within reasonable limits, the form of the statistical distribution of the source variables is irrelevant.

To justify the above hypothesis, at least heuristically, consider the central limit theorem of mathematical statistics. Though this theorem can be expressed in various ways, the following statement suffices for present purposes. If an arbitrary population distribution has mean m and finite variance σ^2 , then the distribution of the sample mean approaches the normal distribution with mean m and variance σ^2/n as the sample size n increases. Sometimes it is said that the distribution of the sample means tends asymtotically to a normal distribution. How large n has to be in order to approach closely to a normal distribution depends on the form of the distribution of the variables being combined. As has been shown in experience with statistical quality control concepts, normality can be closely approached if n is as small as 3 or 4, even if the distributions of the original variables depart markedly from a normal distribution.

Now consider the case of n sources of error--that is, consider n random variables $X_1, X_2, \ldots, X_n$. Perform the logarithmic transformation

$$\log X = \log X_1 + \log X_2 + \ldots + \log X_n$$

or $$Y = Y_1 + Y_2 + \ldots + Y_n$$

where $$Y_i = \log X_i .$$

Then, if the central limit theorem applies, Y will tend asymptotically toward a normal distribution, and this fact implies that in antilog space X will tend toward a log-normal distribution.

There is reason to believe that the sources of variability in automotive exhaust emissions combine multiplicatively. Consider, first of all, errors of measurement in determining the concentration of a particular pollutant in the exhaust stream. Let the error involved in measuring the concentration C be measured by its standard deviation σ . There is reason to believe that σ is proportional to C--that is, that the relative standard deviation or coefficient of variation σ/C is constant for a particular effluent and a particular measurement situation.

Now, consider a particular engine and let its emissions be measured repeatedly by the process under consideration. The actual concentration C will vary from time to time, due to differences in ambient environmental conditions, condition of linkages and engine adjustments, type of fuel, operator-induced variations and the like. It will follow, therefore, that σ will also vary proportionally to C and that the net result will be analogous to the multiplication of two sources of error.

Let us further consider the relationship which obtains between repeated tests of the same automobile and variation among many automobiles in a fleet or in a production output. It might, perhaps, be argued that if a particular automobile has a high mean level of emissions, that same automobile may tend to have highly-variable emissions. Conversely, an automobile having a relatively low mean level of emissions may tend to have relatively constant emissions. A moment's reflection will show that these statements must, to some extent at least, be true. Since emissions are bounded on the low side of the scale (they can not be less than zero), it is impossible for individual emission measurements to range upward beyond a certain level and yet maintain a low mean, unless the high measurements are offset by a large number of measurements close to zero. This bounding process will tend to limit the magnitude of the standard deviation and, at the same time, may tend to produce a skewed distribution which, itself, may resemble a log-normal distribution.

Now consider the combination of vehicle-to-vehicle variability, time-to-time variability within a given vehicle, and test-to-test variability at a given time. If test-to-test variability is proportional to the mean level of the particular automobile at a given time, and time-to-time variability is

proportional to the mean level for the particular vehicle, then the three sources of variability would combine in a multiplicatively way. The result, by virtue of the central limit theorem, would be a log-normal distribution.

Appendix III

DISCRIMINANT FUNCTION ANALYSIS OF AUTOMOBILE EXHAUST EMISSIONS

To provide a greater insight with regard to apparent differences between emissions for different cities or different makes of vehicles, multiple discriminant function analysis was applied to the emission data. The procedure is illustrated in Figure III-1, which presents a hypothetical plot of emission measurements from vehicles in two cities designated simply as City A and City B. In the left-hand part of this figure, the emissions are plotted in three-dimensional space. Both cities exhibit a considerable amount of scatter in the plotted points and, although the two sets of points tend to cluster about a different center of gravity, there is a considerable amount of interpenetration of the two clouds of points. Consequently, it is impossible to construct a plane in the space in such a way that all City A points fall on one side and all City B points on the other.

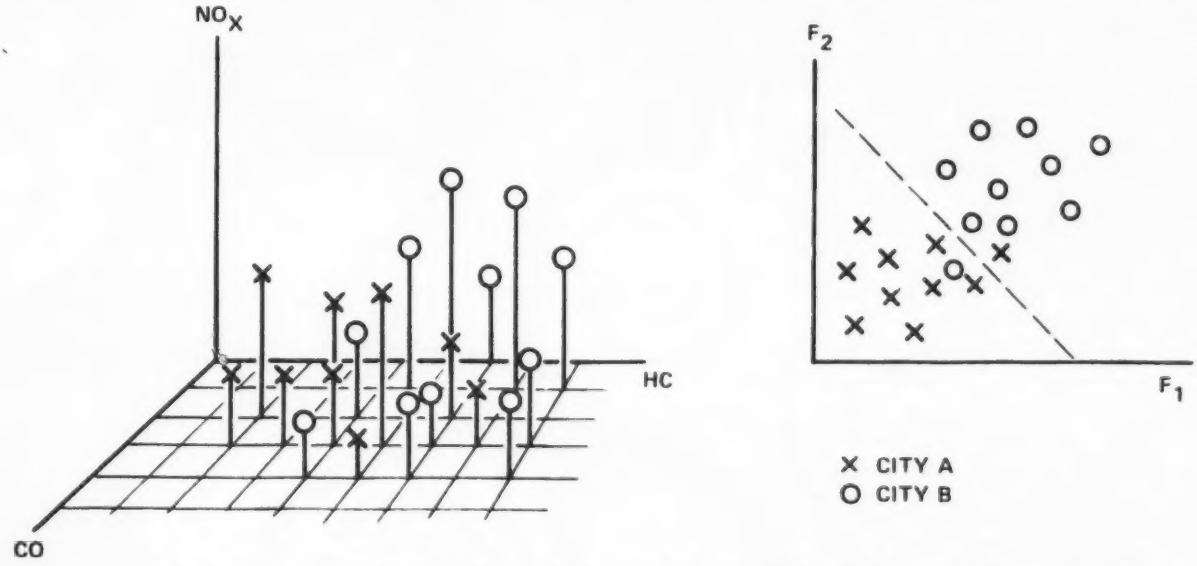

Figure III-1 DISCRIMINANT FUNCTION ANALYSIS OF AUTOMOBILE EXHAUST EMISSIONS

Now consider the right-hand side of Figure III-1. In this two-dimensional plot, two linear combinations of the three emittants are computed:

$$F_1 = a_1(HC) + a_2(CO) + a_3(NO_x)$$

$$F_2 = b_1(HC) + b_2(CO) + b_3(NO_x)$$

The quantities F_1 and F_2 are called discriminant functions and the quantities a_1, a_2, a_3 and b_1, b_2, b_3 are weighting factors selected in such a way as to produce minimum scatter within groups and maximum separation between groups. Though it is still not possible to separate the groups completely, the two sets of points show much less overlap than was previously the case. If such a result can be achieved when comparing emissions from two or more actual cities, then it is clear that a real difference between them is involved.

In the computation of discriminant functions, one of the functions may be much more discriminating than the other. In fact, it may be that substantially all of the discrimination is realized along either the F_1 or F_2 axis. If such is the case, the weaker of the two discriminants can be ignored, and the problem reduces to a one-dimensional problem in which classification of points can be achieved by observing whether a particular point lies to the left or to the right of some critical value. This value is selected (see Figure III-2) in such a way that the two frequency distributions overlap to the least possible degree. The principle involved is that of maximum likelihood, each point being assigned to the group to which it is "most likely" to belong.

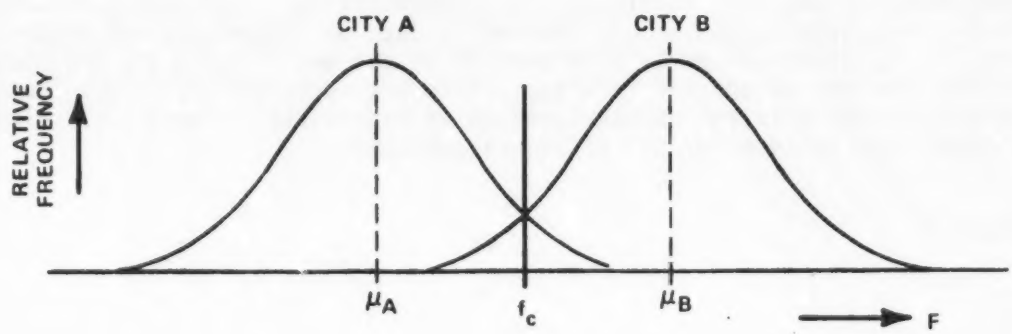

Figure III-2 MAXIMUM LIKELIHOOD DISCRIMINATION

Several points must be made here. First, it is very rare that two sets of data will be found which will show no overlap or intermingling of points. Second, the impression received from a discriminant function plot may be quite different from that obtained if only the mean values of the emittants, or of

discriminant functions derived from them, are considered. As has been previously pointed out, a very minimal difference between the two means μ_A and μ_B may be declared statistically significant, provided the number of observations in the two groups is sufficiently large, yet this difference may be of little practical importance. The implications of this fact can be further appreciated from the discriminant function plots, wherein it is seen that even though the centroids of the two clouds of points may be distinct, the actual amount of overlap of the two distributions precludes strong generalizations concerning a preference for one or the other of the two distributions.

The rationale described above was applied in assessing differences between cities and between vehicle makes. Figures III-3 through III-6 illustrate the analytic process as applied to low mileage 1971 model Chevrolets operating in the four cities Houston, Los Angeles, Detroit and Denver. The first three figures show plots of HC vs CO, HC vs NO_x, and CO vs NO_x. In these plots, each point represents a particular vehicle. The last figure in this group is a plot of the two strongest discriminant functions. Units in this figure are arbitrary but, being weighted combinations of the three effluents, are proportional to grams per mile. Whether one considers the raw data or discriminant-function plots, it is difficult to discriminant one city from another, with the exception of Denver and the possible exception of Los Angeles. Both on the basis of discriminant function plots and the magnitude of differences among the means for the several cities, it was concluded that there is little justification for treating separately any of the cities except Denver.

As is evident in Figure III-6, Denver data is separated from the data from the other cities primarily in the direction of the Factor 1 axis. This fact makes it possible to simplify the comparison by considering only this factor and plotting Denver and non-Denver data as histograms, as shown in Figure III-7. Though there is some overlap of the two histograms, the distinction between the two categories is clear. The plot is particularly meaningful, because it reflects the distinctiveness of Denver not in terms of a single effluent but in terms of all effluents combined.

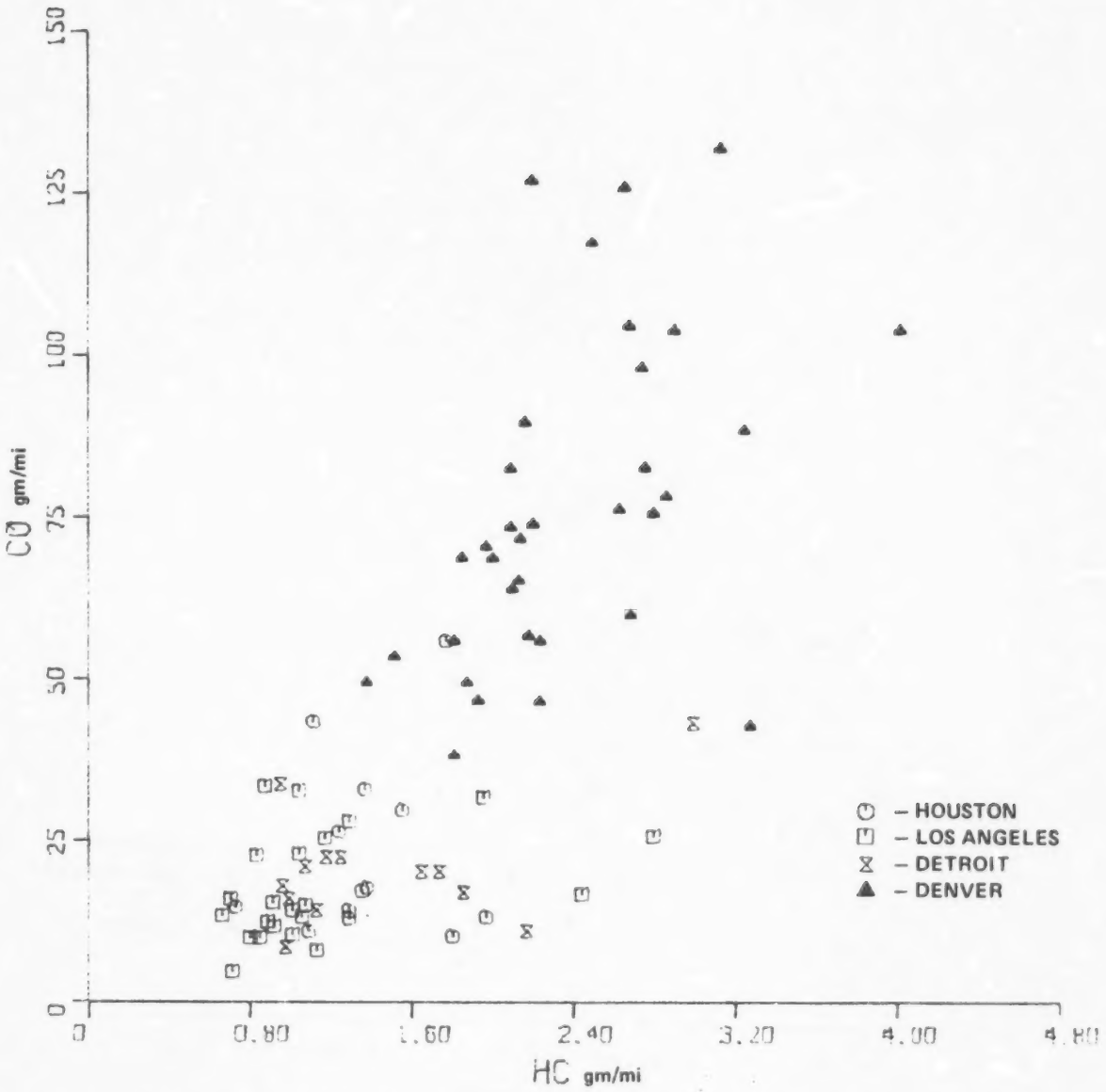

Figure III-3 TWO-WAY PLOT OF EMISSIONS FOR FOUR CITIES 1971 PHASE 1 CHEVROLETS

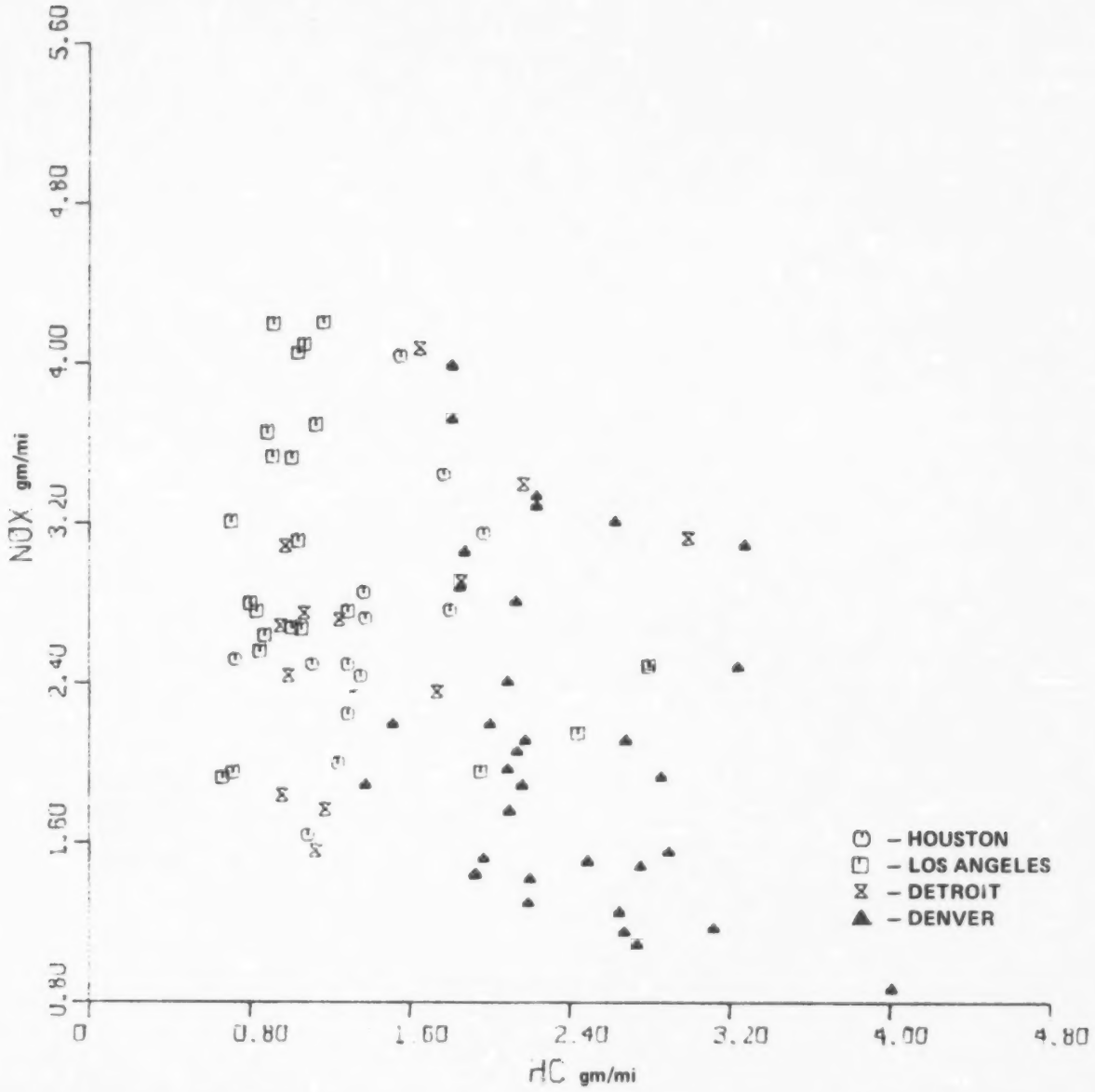

Figure III-4 TWO-WAY PLOT OF EMISSIONS FOR FOUR CITIES 1971 PHASE 1 CHEVROLETS

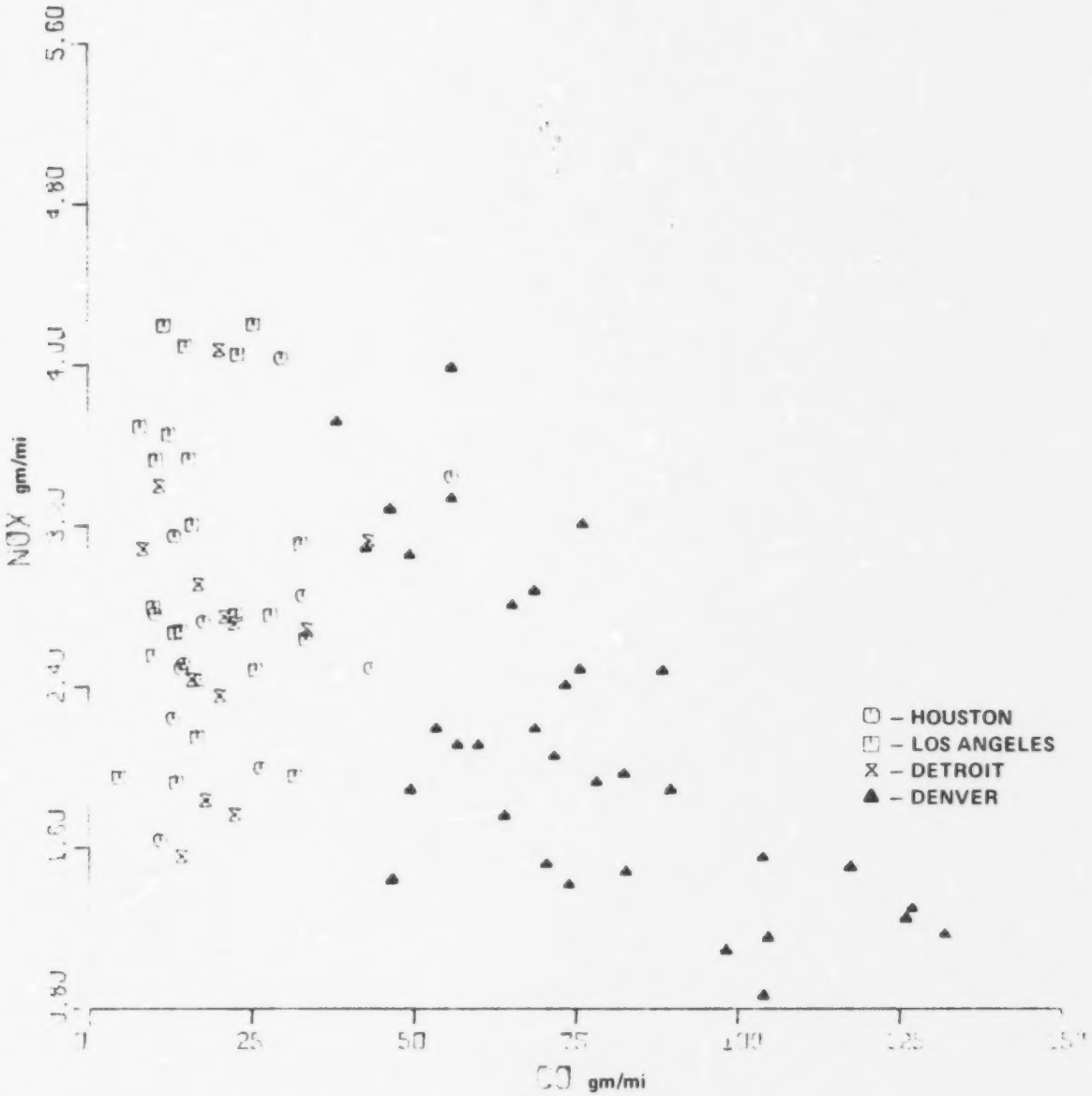

Figure III-5 TWO-WAY PLOT OF EMISSIONS FOR FOUR CITIES 1971 PHASE 1 CHEVROLETS

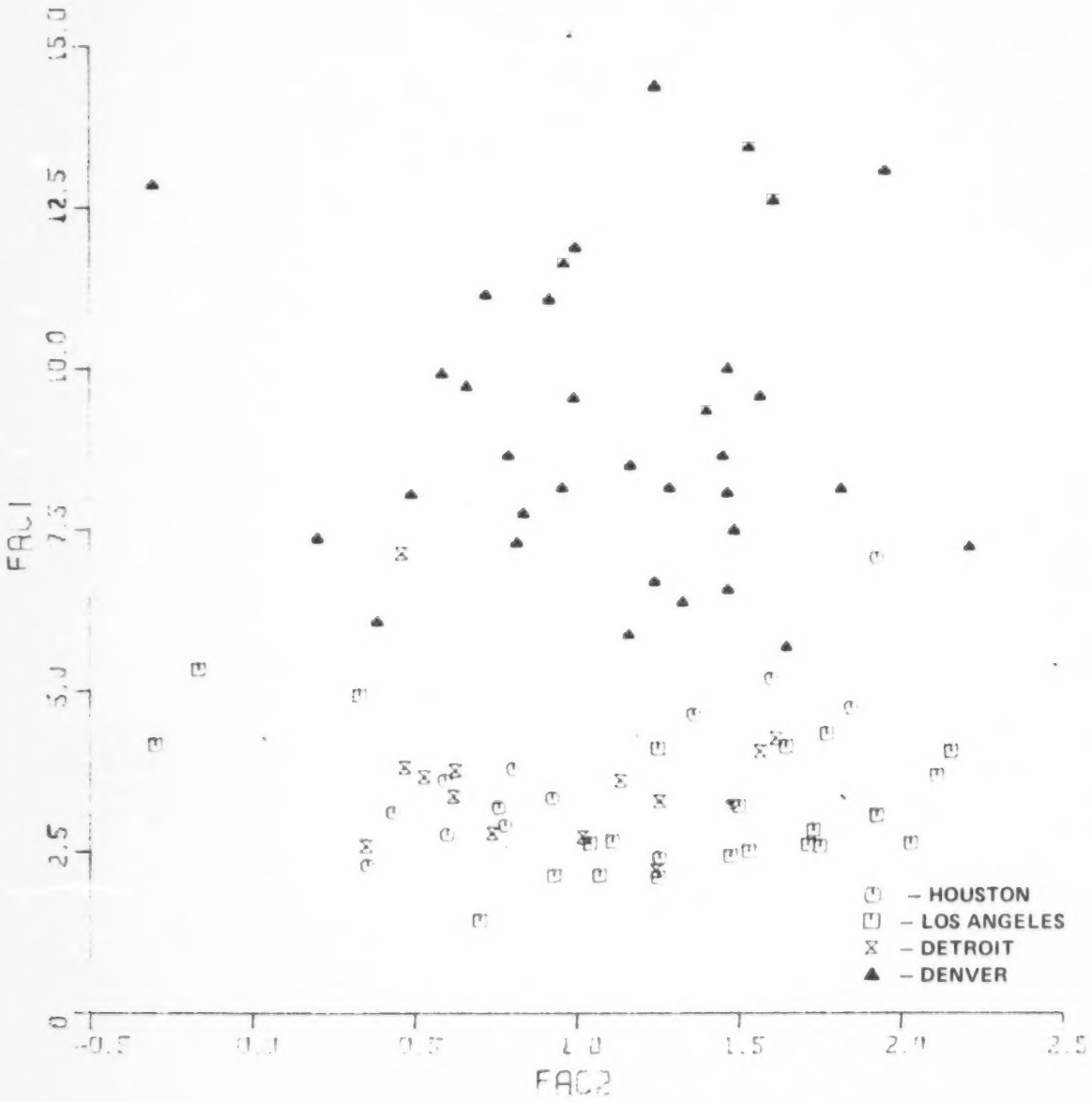

Figure III-6 DISCRIMINANT PLANE PLOT OF EMISSIONS FOR FOUR CITIES 1971 PHASE 1 CHEVROLETS

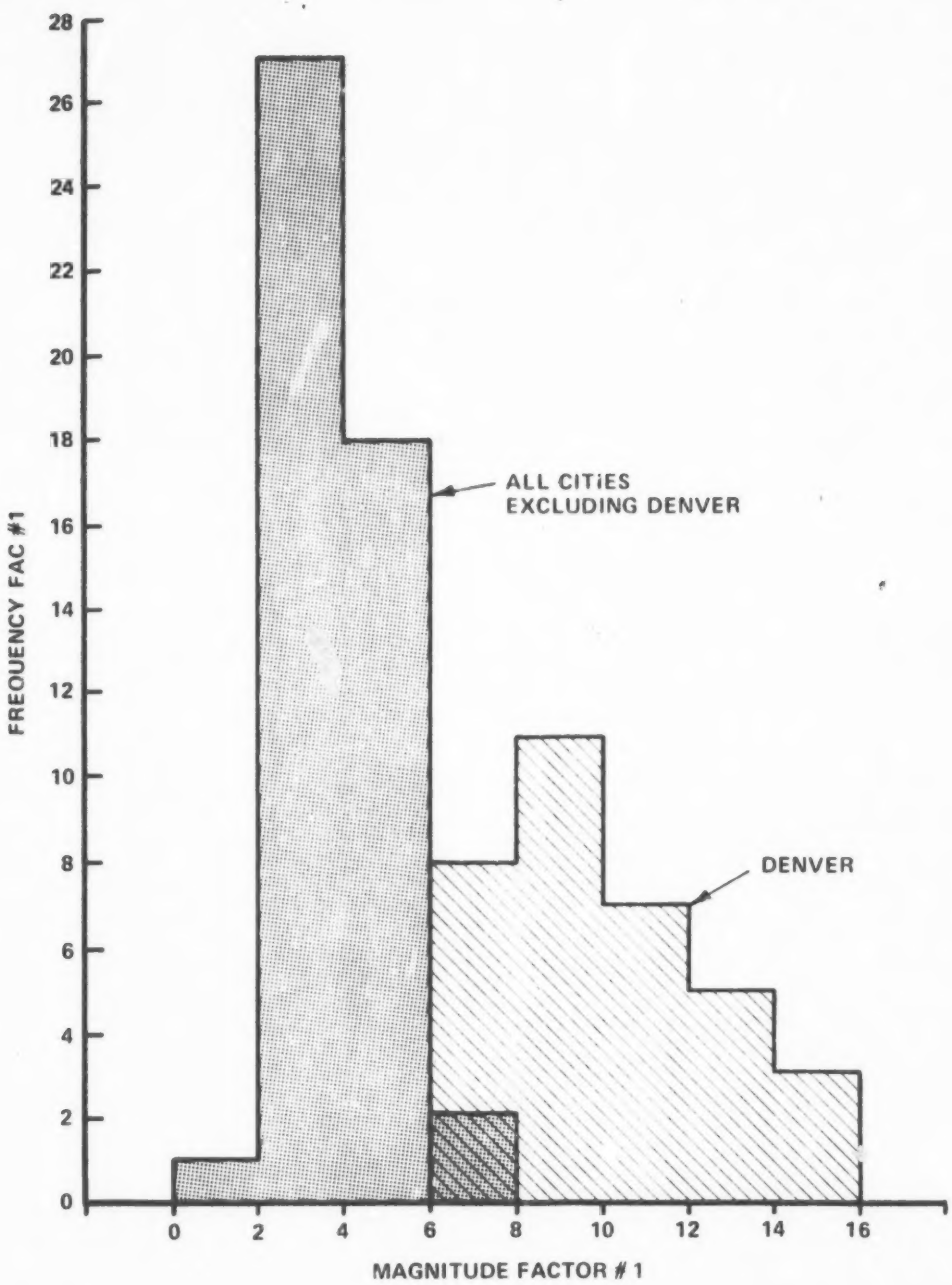

Figure III-7 DISTRIBUTION OF PRINCIPAL FACTOR (1971 PHASE 1 CHEVROLETS) DENVER VS REST